Real-time Prostate Motion Compensation for 2D/3D Ultrasound-guided Biopsy

Derek Gillies, BSc
Supervised by: Dr. Aaron Fenster

Introduction: Biopsy is the current clinical standard for the definitive diagnosis of prostate cancer and is typically guided by two-dimensional transrectal ultrasound (2D TRUS). We have previously proposed the use of three-dimensional (3D) TRUS/MR fusion images during biopsies to improve needle guidance accuracy and diagnoses by augmenting the conventional 2D TRUS guidance. However, prostate motion can cause misalignment of the anatomical and planned targets identified using the 3D TRUS/MR fused images, leading to missed cancer diagnoses and an increase in repeat patient biopsies. To compensate for this motion, and with the overall goal of improving biopsy outcomes, we are developing a real-time continuous registration technique to align 2D and 3D TRUS images.

Methods: Rigid registration between 2D and 3D TRUS images was performed using an intensity based normalized cross-correlation similarity metric optimized with the Powell method. This algorithm was implemented on a TRUS-guided ultrasound system with tracking encoders, then tested on a tissue-mimicking prostate phantom. The phantom was mounted on a micrometer driven stage, providing known translational displacement. 2D and 3D TRUS images were acquired and the algorithm was tested for in-plane and out-of-plane motion up to 12 mm in 1 mm increments. The difference between the measured and corrected registration distance was used to determine error. Rotational compensation around the long axis of the TRUS transducer in 1° increments up to 15° was also tested. Rotational differences were calculated between encoder displayed rotations and corrected rotation matrices to determine error. These procedures were experimented with single and continuous background image registration techniques.

Results: When performing translation motion compensation with the continuous method, average differences of $0.6 \pm 0.5$ mm and $0.2 \pm 0.2$ mm were determined for out-of-plane and in-plane motion, respectively. When performing rotational motion compensation, an average difference of $0.8 \pm 0.4$° was observed. The average registration computation time when observing all displacements was observed to be $31 \pm 5$ ms. This was compared to a single user initiated correction with average differences of $1.5 \pm 1.4$ mm, $0.5 \pm 0.5$ mm, and $1.5 \pm 1.6$° for out-of-plane, in-plane, and rotational motions, respectively. The average registration computation time when observing the user initiated correction for translational compensation was $76 \pm 32$ ms and $113 \pm 49$ ms for rotational compensation.

Discussion and Conclusions: Continuous motion compensation was superior to single image registration when investigated on the rigid fabricated phantom. Although these results are promising, variable motions speeds were not tested and prostate deformation may lead to an increased registration error. Future work will involve validating the continuous background motion compensation algorithm on patients undergoing biopsy procedures.