Image-guided prostate cancer brachytherapy: Automatic needle segmentation using 3D ultrasound

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**Background:** High-dose-rate (HDR) brachytherapy is a treatment option for intermediate and high-risk prostate cancer involving the insertion of 14-20 hollow needles into the gland to temporarily deliver a high-activity radiation source while the patient is anesthetized. Clinical trials indicate that this technique yields improved disease-free survival relative to external beam radiation therapy (1). HDR brachytherapy treatment planning requires localization of needles relative to anatomy using 3D ultrasound images. Needle segmentation is currently performed manually, increasing the time patients must be anesthetized by approximately 10 minutes. Automating needle segmentation could decrease this time, but existing algorithms are only designed to process images containing a single needle. The purpose of this study is to present an automatic needle segmentation algorithm for 3D ultrasound images containing 14-20 needles, and to compare manual and automatic needle segmentations using 3D ultrasound images from HDR prostate brachytherapy patients.

**Methods:** The automatic needle segmentation algorithm was implemented using MATLAB 2015a (Mathworks, Natick MA, USA). Twelve intermediate-risk prostate cancer patients underwent HDR brachytherapy, during which 3D ultrasound images were acquired for analysis. Needle segmentations were produced manually and using the algorithm. Tip errors were assessed in terms of the 3D Euclidean distance between needle tips, and trajectory error was assessed in terms of 2D distance in the axial plane and angular deviation between trajectories.

**Results:** 188 needles were analyzed. Mean execution time of the algorithm was 11.0 s per patient, or 0.7 s per needle. The algorithm identified 84% of needle tips with 3D errors ≤3 mm, 91% of needle trajectories with 2D errors in the axial plane ≤3 mm, and 83% of needle trajectories with angular errors ≤3°. The largest tip error component was in the needle insertion direction.

**Conclusions:** To the authors’ knowledge, this is the first needle segmentation algorithm designed to segment multiple adjacent needles in 3D ultrasound images. The algorithm shows promise for reducing the time required for needle segmentation; however, tip localization remains as a major limitation. Future work involves improving needle tip localization performance through improved image quality and curved trajectory modelling.