Real-Time Segmentation of Trans-urethral Ultrasound Images for Prostate Brachytherapy

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Abstract. Previous research on Trans-urethral Ultrasound (TUUS) imaging has shown promise that TUUS will become a viable new intra-operative tool. Prior work focused on the processing of TUUS data in order to obtain useful clinical information, however intra-operative imaging issues (real-time feedback) have not been fully addressed. This paper describes a unique framework for efficient processing which can be used for intra-operative imaging. The methods describe a segmentation pipeline which meet the requirements of intra-operative imaging in prostate brachytherapy. The implementation of the process is described and the process is evaluated for efficiency and accuracy.

Trans-urethral Ultrasound (TUUS) has demonstrated potential as a diagnostic and therapy-guidance tool[1]. Early papers by our group focused on the ability of TUUS to acquire anatomically and physiologically relevant information [1]. Subsequent work emphasized on therapy guidance applications for prostate brachytherapy [1]. Because large amounts of TUUS image data is generated during patient procedures, analysis of the data has been conducted offline. Several custom algorithms have been designed for improved efficiency and reproducibility. With the successful demonstration of offline analysis of TUUS data, design and development of intra-operative processing methods have been undertaken.

1 Methods

TUUS data was collected with the Acuson AcuNav 3D catheter. In order to simulate intra-operative data collection and processing, individual frames were "submitted" to the processing steps in a manner similar to that anticipated in on-line acquisition and processing. As the data is collected, the raw images are stored to disk while individual frames are passed to the segmentation process. The "boundary segmenter" first filters the data with an edge-enhancing filter and then applies a snake-like segmentation algorithm for contour extraction [2]. The "seed segmenter" filters the data using math morphology [2]. The resulting contour and seed locations are transformed into Cartesian coordinates and stored efficiently as surface models in SGI Inventor format.

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2 Results

Several data volumes have been processed, and evaluated, including canine data, phantom data, and in-vivo human data. US image data is typically acquired at 30 frames/sec, whereas the boundary and seeds are processed at a rate of 10-12 frames/sec. Therefore, it was necessary to discard certain frames during the processing. Given the angular resolution of the system (approximately 0.4°), the dropped frames do not visibly diminish the quality of the segmentation of the 3D prostate or of implanted radioactive seeds, as is seen in Figure 1. Initial assessment of the accuracy of the method reveals a trade-off between the speed of the system and the accuracy of the results. Because segmentation algorithms were chosen to be "one-pass" algorithms (in the interest of speed), differentiation of the small seeds from noise was difficult. A few seeds were missed while speckle was sometimes classified as a seed. However, the accuracy of the seed segmentation was approximately 82% which is considered clinically useful. Boundary segmentation was within clinically acceptable variation.

3 Conclusions

Because the implementation of this framework closely resembles the acquisition methods for TUUS data during a procedure, feasibility of an intra-operative imaging procedure has been shown. The method is sensitive to the quality of the raw data, but improved processing will result in higher accuracy. Future designs incorporate in-line filters which will normalize and condition the data to reduce bias or errors. With these methods in place, a clinician will be able to intra-operatively assess the placement of brachytherapy seeds, or monitor other therapy procedures such as cryotherapy or thermotherapy, with rapidly-acquired, high-resolution 3D images from TUUS devices.

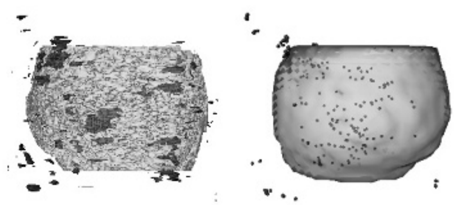

Fig. 1. Comparison of manually segmented prostate(left) and automatically segmented prostate(right). Brachytherapy seed locations are shown as dark objects.

References

1. Holmes DR 3rd, Davis BJ, and Robb RA. Trans-urethral ultrasound: A new tool for diagnostic and therapeutic imaging in prostate cancer. In Lecture Notes in Computer Science: Medical Image Computing and Computer-Aided Intervention, 2001.
2. Holmes DR III. Trans-urethral Catheter-based Ultrasound Image Acquisition, Processing and Visualization for Applications in the Prostate. Doctoral Thesis, Mayo Foundation, 2002.