

3D Prostate Segmentation in Ultrasound Images using Image Deformation and Shape Fitting

Seyedeh Sara Mahdavi¹, Septimiu E. Salcudean¹, James Morris², Ingrid Spadinger²

¹ Department of Electrical and Computer Engineering, University of British Columbia, 2356 Main Mall, Vancouver, BC, V6T 1Z4, Canada, {saram, tims1@ece.ubc.ca}

² Vancouver Cancer Centre, British Columbia Cancer Agency, Vancouver

1 Introduction

Prostate cancer is the second leading cause of cancer death in men affecting one man in six during their lifetime. In prostate brachytherapy to generate a plan of the seed positions, a pre-operative volume study is carried out by obtaining 8-14 transverse 2D ultrasound images. These images are then manually segmented which is both time consuming and dependent on the experience of the oncologist. In addition, the prostate is poorly delineated in ultrasound images making its automatic segmentation a challenging task. The proposed semi-automatic 3D segmentation method, based on [1], greatly reduces the segmentation duration and produces good results while being less sensitive to the user's experience and image quality.

2 Method

Segmentation is initialized by the user selecting the midgland, base and apex slices and five specific points on the midgland slice (Fig. 1). With the aid of these points, the algorithm un-warps all the images to reduce the posterior deformation of the prostate due to the presence of the trans-rectal ultrasound probe. It then fits a tapered ellipse on the resulting image producing a tapering value, t , which is employed to un-taper the prostate in all other slices. It is assumed that t is maximum in the midgland slice and linearly reduces to zero towards the base and apex.

The resulting shapes are closer to ellipses, hence simplifying the problem to a convex problem. With the aid of the IMMPDA edge detector [2] a final ellipse is fitted to the prostate at the midgland. Using this ellipse and the positions of the base and apex, two semi-ellipsoids are drawn and sliced to guide the IMMPDA and the ellipse fitting process in the rest of the slices. These contours are further used to create the 3D volume.

Fitting an ellipsoid, although another convex problem and a very fast procedure, reduces accuracy due to the shape of the prostate being more tapered towards the apex. Fitting a 'tapered' ellipsoid ('egg' shape) is thus considered more suitable. The Levenberg-Marquardt method was used for this purpose. However, since the speed and convergence of this optimization method greatly depends on its initial values, to get as close as possible to the actual solution, an ellipsoid is primarily fitted and then

deformed to a tapered ellipsoid. The final volume is sliced and reversely, the slices are tapered using the initial values and warped to match the original images (Fig.1).

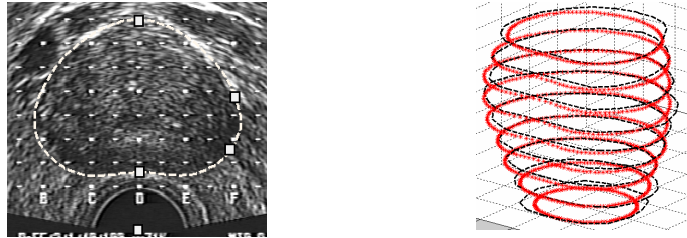


Fig. 1. The final generated contour on the midglnd slice along with the 5 initial points (left), the final 3D volume of the prostate (right) compared to the manual contours (dashed)

3 Results

The 3D segmentation algorithm was applied to 39 randomly selected volume studies obtained from the BC Cancer Agency. The resulting semi-automatic contours, initialized by a non-expert, were compared to manual contours generated by expert oncologists with the manual contours treated as the gold standard. Table 1 shows the Mean Absolute Difference, Maximum Distance, sensitivity and accuracy, the last two calculated for three regions of the prostate.

Results show that this method can generate reasonable contours in almost real time (compared to the 5-10 min manual segmentation procedure) without greatly depending on the experience of the user.

Table 1. Comparison of semi-automatic to manual segmentation

	Superior (slices 2-3)	Middle (slices 4-8)	Inferior (slices 9-10)
Sensitivity (%)	83.4	96.8	92.2
Accuracy (%)	74.4	85.1	67.2
MAD (mm): 2.64±0.35		MAXD (mm):6.27±0.46	
Duration (s): 8.6 (Intel Core 2 Duo, 2GB laptop)			

References

1. Badieli, S., Salcudean S., Varah,, J., Morris J.: Prostate Segmentation in 2D Ultrasound Images using Image Warping and Ellipse Fitting. In: Conf. Medical Image Computing and Computer-assisted Intervention, pp. 17--24 (2006)
2. Abolmaesumi, P., Sirouspour, M.: An interacting multiple model probabilistic data association filter for cavity boundary extraction from ultrasound images. In: IEEE Trans. Med. Imaging, vol. 23, pp.772--784 (2004)