Accurate Prostate Volume Determination from T2-w MRI using Statistical Shape Models

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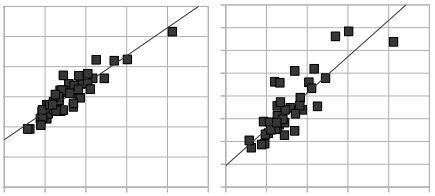
Introduction: Prostate volume is highly indicative of treatment outcome for patients with prostate cancer, and is used in determining PSA density [1-3]. The currently clinical standard is for a clinician to manually determine the anterior-posterior, transverse, and cranio-caudal lengths of the prostate, and to use these measurements to model the prostate as an ellipsoid [4]. However, this can be time consuming and subject to inter- and intra- observer variability. We aim to automatically segment that prostate on each slice of a 3D MR stack using an advanced Active Shape Model (ASM) [5] system, donned a multi-feature ASM (MFA), and to use these segmentations to determine the volume of the prostate.

Methods: We extract $N = 100$ equally spaced landmarks $X = \{c_n, n \in \{1, \ldots, N\}\}$, $c_n = [x_n, y_n]$ along the prostate boundary on each training slice. Principal component analysis (PCA) is used to extract the top $d = 10$ eigenvectors P describing the prostate shape, so that $X_b = X_\mu + P * (b \cdot \sqrt{\lambda})$ where $b \in \Re^d$ describes the shape, $P \in \Re^{2Nxd}$ contains the eigenvectors, $\lambda \in \Re^d$ contains the eigenvalues, and X_μ is the mean landmarks over all training images. Each training image is convolved with k kernels (such as a Gaussian kernel), in essence describing the texture at each pixel in the image. For each landmark n, the k texture features are extracted and a k-dimensional Gaussian distribution constitutes the appearance model. To segment a new image (one that was not included in the training set), the pixels Y which contain the highest probabilities of belonging to the appearance model are selected. To constrain it to only valid prostate shapes, b is modified between -3 and +3 standard deviations, such that X_b is closest to the selected pixels Y, as per the method described in [5]. The number of pixels determined to lie within the prostate on each slice is then determined, and the prostate volume is thus estimated as V_{MFA} based on pixel size and interslice spacing.

Results: For our experiments, we used 45 3D, T2-weighted endorectal prostate studies. An expert radiologist segmented each slice of each MR stack, and the volume obtained by the expert is denoted as V_{Ex}. In addition, an expert radiologist determined the anterior-posterior (d_1), transverse (d_2), and cranio-caudal (d_3) lengths of the prostate, and the clinically used ellipsoid formula was used to determine the volume of the prostate as $V_{Ell} = d_1 \cdot d_2 \cdot d_3 \cdot \pi/6$. The results showed that the V_{Ell} had a correlation coefficient R^2 with V_{Ex} of 0.70 while V_{MFA} had an R^2 value 0.82. A scatter plot of the volume estimations are shown in Figure 1, in which it can be seen that V_{ASM} and V_{Ex} (a) were more correlated than V_{Ell} and V_{Ex} (b).



(a) (b)

Figure 1. (a) shows V_{ASM} on the Y-axis and V_{Ex} on X-axis, while (b) shows V_{Ell} on the Y-axis and V_{Ex} on X-axis

Concluding Remarks: We have shown that using an automatic MFA segmentation scheme, accurate prostate volumes can be determined from T2-weighted MR images. In addition, we have shown that the MFA volumes are more consistent with expertly determined volumes than the current clinical standard. Future work will entail generating more accurate segmentations and testing on a larger dataset.

References:

1. P. Pierorazio, M. Kinnaman, M. Wosnitzer, M. Benson, J. McKiernan, E. Goluboff, "Prostate volume and pathologic prostate cancer outcomes after radical prostatectomy", Urology 70 (2007) 696–701.
2. C. Roehrborn, P. Boyle, D. Bergner, T. Gray, M. Gittleman, T. Shown, A. Melman, R. Bracken, R. White, A. Taylor, D. Wang, J. Waldstreicher, "Serum prostate-specific antigen and prostate volume predict long term changes in symptoms and flow rate: Results of a four-year, randomized trial comparing finasteride versus placebo", Adult Urology (1999), 662–670.
3. J. Kaminski, A. Hanlon, E. Horwitz, W. Pinover, R. Mitra, G. Hanks, "Relationship between prostate volume, prostate-specific antigen nadir, and biochemical control", International Journal of Radiation Oncology and Biological Physics 52 (2002) 888–892.
4. C. Bangma, A. Niemer, D. Grobbee, F. Schroder, Transrectal ultrasonic volumetry of the prostate: In vivo comparison of different methods, The Prostate 28 (1996) 107–110
5. T. Cootes, C. Taylor, D. Cooper, J. Graham, "Active shape models – their training and application", Computer Vision and Image Understanding 61 (1995) 38–59.