Prostate Segmentation on MR Images without Endorectal Coil

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Introduction: Accurate detection of prostate boundaries is required in many diagnostic and treatment applications. Most of the published prostate segmentation works have been done on sonographic images because of its application in brachytherapy as the treatment for prostate cancer. With the introduction of conformal radiotherapy (CRT) and intensity modulated radiotherapy (IMRT) for prostate cancer, accurate delineation of tumor target volume and organs at risk becomes increasingly important in radiotherapy treatment planning. Superb soft tissue contrast can be achieved on MRI on T2-wighted images, which show in much more detail of the internal prostatic anatomy and prostatic margins (1). In this study, a shape constrained level set segmentation method was tested on prostate T2-weighted MR images without the use of endorectal coil. A general introduction into level set theory can be found in (2). An obvious advantage of not using endorectal coil is to improve patient compliance. It also makes fusion with CT data easier in radiotherapy treatment planning. The cost is also relatively lower.

Methods: MR examinations of 5 volunteers were performed on a 1.5-T whole-body MR imaging system (Siemens Sonata). T2-weighted (TR/TE, 3200/133) transverse images of pelvis were obtained with 3.5 mm slice thickness, 448×291 matrix and a field-of-view of 23×23cm^2. Twenty four transverse slices were obtained and each slice was saved as an 896×896×16 bit DICOM file. Figure 1 shows the visualized dataset consisting of 24 transverse slices. A cubic volume of interest (VOI) containing the prostate was then extracted by a simple image pre-processing method. Then, a level set based segmentation method was performed on each slice to extract the prostate boundary. The boundary was represented as a closed curve C(t) and evolved according to the partial differential equation:

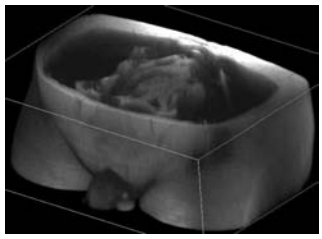
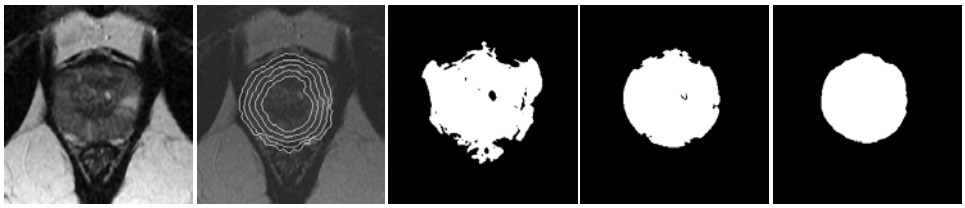


Fig. 1 T2-weight pelvic MR image

$$\frac{\partial}{\partial t}C(t) = F\overline{N}$$

$\overline{N}$ is the normal vector. F represents the sum of the forces driving the evolution. Three driving forces were used in this application: the external force determined by the image being processed; the internal force reflecting the boundary's geometry; and a third force that incorporates the information from priori shape knowledge. The priori shape was generated from manually outlined boundaries using a curve averaging method reported in (3) and represented as Fourier descriptors.

Results: Figure 2(a) is a slice of the VOI. The evolution of the level set curve was illustrated in Fig. 2(b). As shown in Fig. 2(c), boundary leaking occurred when the traditional level set method was used. This type of failure can be remedied partially by adjusting the curvature force as shown in Fig. 2(d). When shape constraints were applied, smoother boundaries can be obtained as in Fig. 2(e). A three dimensional surface model of the prostate was then reconstructed from the traced boundaries as illustrated in Fig. 3(a). A set of shape curves was presented in Fig. 3(b).



(a) (b) (c) (d) (e)

Fig. 2 (a) Extracted ROI (b) Level set evolution (c) Boundary leak (d) Curvature force applied (e) Shape constraint applied

Discussion and Conclusion: It is difficult to perform fully automated segmentation in T2-weighted images because the signal intensity within the prostate is inhomogeneous as it reflects the underlying characteristics of the glandular tissue (4). The interface between the prostate and the rectum and bladder is not always clear. Some parts of the boundary defined by the prostatic capsule are less distinct because the fibromuscular band blends with urethral sphincter at the prostate apex and bladder musculature at its base. These weak boundary features can cause 'leaking' when level set curve evolves. The priori shape knowledge used as constraints was proven to be an effective solution to this problem. The segmentation results were visually validated only at this preliminary stage. Further studies should include quantitative validation of the results. The evaluation method proposed in (3) is a candidate approach. The segmentation of the central gland and peripheral zone is also of interest. The feasibility of prostate segmentation on MR images without endorectal coil is significantly beneficial to CRT and IMRT. The advantages include the less deformation of the prostate structure, improvement in patient comfort, and expected better outcome from fusion with CT images.

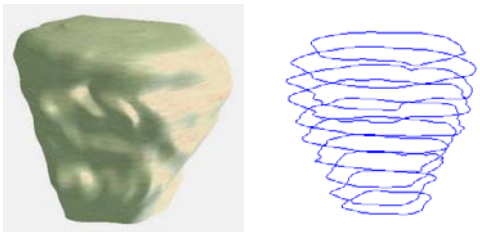


Fig. 3 (a) The rendered 3D prostate (b) Shape priori

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