Measurement of Volume of Urinary Bladder by Implementing Localizing Region-Based Active Contour Segmentation Method

B. Padmapriya, T. Kesavamurthi, B. Abinaya and P. Hemanthini

Abstract Ultrasound has become increasingly important in medicine and has now taken its place along with X-ray and nuclear medicine as a diagnostic tool. Its main attraction as an imaging modality lies in its non-invasive characteristic and ability to distinguish interfaces between soft tissues. Diagnostic ultrasound can be used to find out the cyst and tumors in the abdominal organs. Considering the importance of measurement of volume of the urinary bladder using diagnostic ultrasound imaging, an image processing technique of edge-based image segmentation has been employed. The technique discussed in this paper deals with a method for automatic edge-based image segmentation of the urinary bladder using localized region-based active contour method from a 2D ultrasound image for finding the area and volume of the urinary bladder accurately. The study of area and volume would provide valuable information about the abnormalities of the bladder and also the extent of abnormality. Experimental results show good performance of the proposed model in segmenting urinary bladder to measure its exact area and volume.

Keywords Diagnostic ultrasound · Urinary bladder · Edge-based segmentation · Localized region-based active contours

B. Padmapriya (✉) · B. Abinaya · P. Hemanthini
Department of Biomedical Engineering, PSG College of Technology, Coimbatore, India
e-mail: priyadhileep@yahoo.co.in

T. Kesavamurthi
Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore, India

G. S. S. Krishnan et al. (eds.), *Computational Intelligence, Cyber Security and Computational Models*, Advances in Intelligent Systems and Computing 246,
DOI: 10.1007/978-81-322-1680-3_13,

1 Introduction

Bladder ultrasound is used in the acute care, rehabilitation, and long-term care environments. It is a non-invasive alternative to bladder palpation and intermittent catheterization used to assess bladder volume, urinary retention, and post-void residual volume in post-operative patients who may have decreased urine output; in patients with urinary tract infections (UTIs), urinary incontinence, enlarged prostate, urethral stricture, neurogenic bladder, and other lower urinary tract dysfunctions; or in patients with spinal cord injuries, stroke, and diabetes.

Considering the importance of measurement of volume of the urinary bladder, a novel approach using edge-based image segmentation has been employed. The technique discussed in this paper deals with a method for automatic edge-based image segmentation of the urinary bladder from a 2D ultrasound image for finding the area and volume of the urinary bladder accurately. The study of area and volume would provide valuable information about the abnormalities of the bladder and also the extent of abnormality.

Figure 1 shows the bladder ultrasound image of a normal person. The noise present in the image is suppressed by the application of a Gaussian filter.

At present, the area and volume of the bladder are obtained by a trackball arrangement. Here, the operator marks points over the boundary manually. The marked points are approximated into an ellipsoid, as shown in Fig. 2, and then, the area and volume of the ellipsoid are calculated.

This value is considered as the volume of the urinary bladder. The accuracy of this method depends on the tracking points marked by the operator.

The volume can then be calculated using the formula for a prolate ellipse [1]

$$\text{Volume} = \pi/6(W \times D \times H) \tag{1}$$

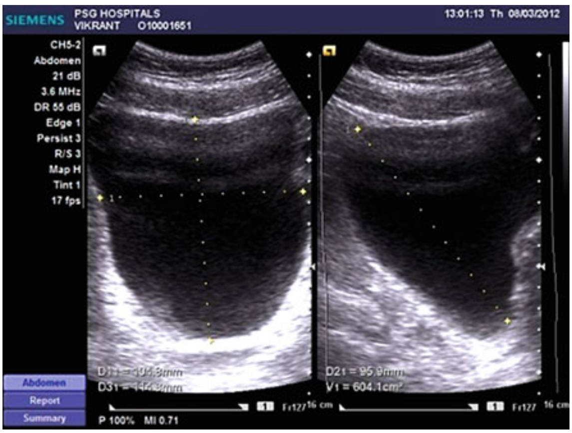

Fig. 1 Bladder ultrasound image

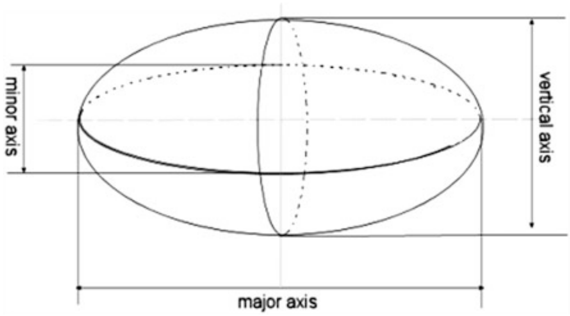

Fig. 2 Ellipsoid method

The width (*W*) and the height (*H*) of a bladder are measured from the transversal view of the ultrasound image. The depth (*D*) is the maximum distance in the sagittal view of the ultrasound image [2].

In general, the bladder was assumed an ellipsoid or even spherical configuration when filled with urine [1] in the present clinical studies, and the increase in the urine volume in the bladder was assumed linear. These suppositions are the major factors causing inaccurate estimation of bladder volume.

Here, we propose a method, which helps to accurately calculate the volume of the bladder.

1.1 Localized Region-Based Active Contour

For segmentation method, localized region-based framework for guiding the active contour is used in this study. This framework allows the foreground and background to be described in terms of smaller local regions, removing the assumption that foreground and background regions can be represented with global statistics. Image is defined on the frequency domain, and *C* is a closed contour represented as zero level of a signed distance function φ. First, specify the interior of *C* by following approximation of the smoothed Heaviside function:

$$H\varphi(x) = \begin{cases} 1, & \varphi(x) < -\varepsilon \\ 0, & \varphi(\&x) \geq \varepsilon \end{cases} \quad (2)$$

For the exterior of *C*, it is defined as $(1 - H\varphi(x))$. To specify the area around the curve, the derivative of $H\varphi(x)$, which is a smoothed version of direct delta, is used [3]. The characteristic function in terms of a radius parameter, *r*, is

$$B(x, y) = \begin{cases} 1, & \|x - y\| < r \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

where *r* is used to mask the local regions. Energy function in terms of a generic force function, *F*, can be defined using $\mathcal{B}(x, y)$. The energy function is as follows:

$$E(\varphi) = \int \Omega x \; \delta\varphi(x) \; \int \Omega y \; \mathcal{B}(x, y) \cdot F(I(y), \; \varphi(y))\mathrm{d}y\mathrm{d}x \tag{4}$$

F is a generic internal energy measure used to represent local adherence at each point along contour. *E* only considers contributions from the points near the contour [4].

$\delta\varphi(x)$ in the outer integral over x ensures that the curve will not change the topology by spontaneously developing new contours. Every point x selected by $\delta\varphi(x)$, mask with $\mathcal{B}(x, y)$, ensures that F operates only on local image information about x. To keep the curve smooth, a regularization term is added. Penalize the arc length of curve and weigh this penalty by a parameter λ. The final energy is as follows:

$$E(\varphi) = \int \Omega x \; \delta\varphi(x) \; \int \Omega y \; \mathcal{B}(x, y) \cdot F(I(y), \; \varphi(y))\mathrm{d}y\mathrm{d}x + \lambda \int \Omega x \; \delta\varphi(x)\|\nabla\varphi(x)\|\mathrm{d}x \tag{5}$$

From Eq. (5), the following evolution equation is obtained:

$$\frac{\partial\varphi}{\partial t} = \delta\varphi(x) \int \Omega \mathrm{y} \; \mathcal{B}(x, y) \cdot \nabla\varphi(\mathrm{y}) \; F(\mathrm{I(y)}, \; \varphi(y))\mathrm{d}y\mathrm{d}x \tag{6}$$

Notice that, F variation with respect to φ can be computed. All region-based segmentation energies can be put into this framework. The detailed explanation of active contour methods is discussed in [5].

2 Materials and Methods

Numerous data of human urinary bladder ultrasound images were collected. The data had been processed using various image processing techniques such as image enhancement and segmentation and measurement to get the values of height, width, and depth of the bladder. Even though the entire image enhancement is done automatically, the initialization masks still need to be done manually, which finds the region of interest.

In this work, we focused on the technique to improve the quality and information of the content of ultrasound images of the bladder, which includes filtering to suppress speckles and localized region-based active contours to segment the region of interest.

2.1 Ultrasound Image Filtering

Transverse and sagittal views of bladder ultrasound image are used in this study. Therefore, the measurements taken in the study are depth (D) and area of bladder region. The ultrasound image is in RGB type, which is an additive color of red,

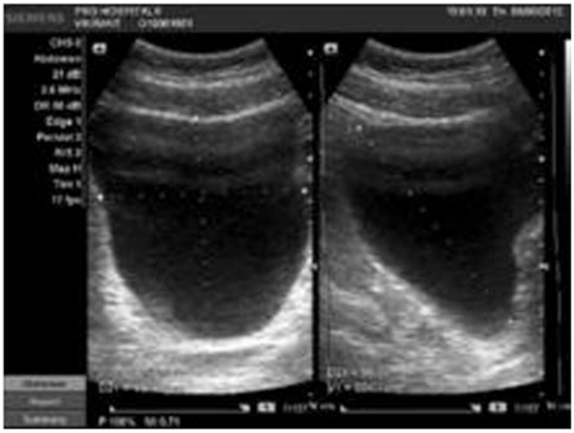

Fig. 3 Bladder image after filtering

green, and blue. The image is first converted into grayscale image for further processing. Image processing toolbox provides image enhancement routines.

The filtering of the image can be observed by applying fspecial [enhances image using Gaussian filter (5 × 5)]. The resulting image after applying fspecial on the original image is shown in Fig. 3. For the segmentation method, traversal view of the bladder is considered. For this purpose, the suitable initialization mask is created for the bladder region, as shown in Figs. 4 and 5.

Resizing the image pixels into the region of interest using initialization mask is significant for efficient image processing. For further processing, the bladder image and initialization mask are segmented using the localized region-based active contour method. The result for the segmentation is shown in Fig. 6. The boundaries or edges of the region behind the mask are detected using suitable operators to find out the region of interest. The data measured are in pixel unit. The numbers of pixels are then converted into its area and displayed. For the sagittal view of bladder region, the methodology is similar to the transversal view, but only

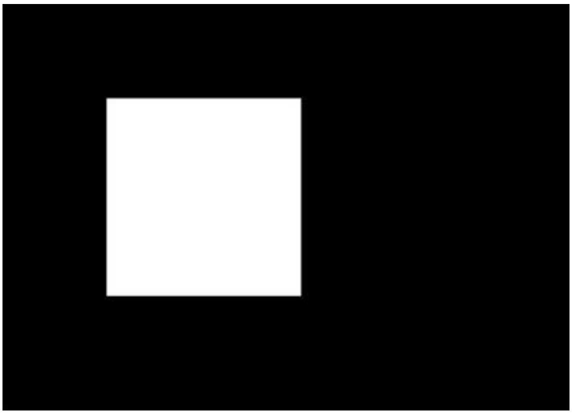

Fig. 4 Initialization mask

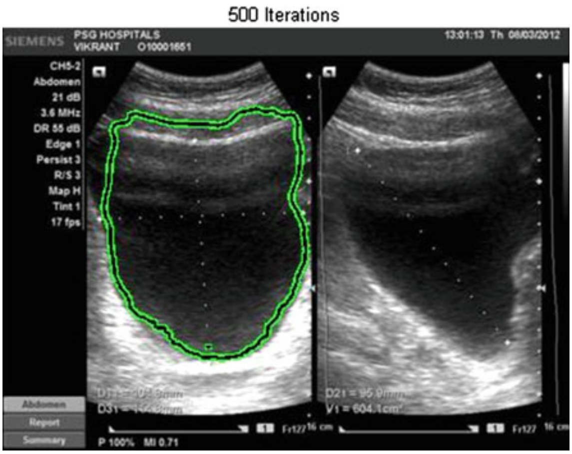

Fig. 5 Localized region-based active contour

Fig. 6 The binary image from localized region-based active contour

the initialization mask value differs. Finally, the area is displayed in square centimeters. The area is then multiplied by the depth parameter which is obtained in units of centimeters from sagittal ultrasound image to obtain the volume of the bladder in cubic centimeters [6].

3 Results and Discussions

The measurements for depth and area of human urinary bladder are represented in SI unit (centimeter). Experiments involve five samples of human urinary bladder ultrasound image from different people. The number of pixels counted was converted into the area and multiplied with the depth parameter to find the volume of

Table 1 The measurements of calculated volume through image processing technique by ultrasound machine and actual volume of five people

Volume in cm^3 (machine reading)	Calculated volume in cm^3 (Proposed methodology)	Actual (voided) ± Residual volume (5 cm^3)
604	619	616
271	308	305
204	199	197
204	199	197
230	220	217

the urinary bladder. The accuracy of our proposed method is close to the actual voided volume of urine. As per the readings obtained in Table 1, the accuracy is almost 98 %.

4 Conclusion

Ultrasound images are widely used as a tool for clinical diagnosis. Therefore, a convenient system for bladder segmentation, volume measurement, and ultrasound image's noise reduction is of particular interest. The proposed MATLAB method includes image noise reduction using Gaussian filter. The experiment results show that the proposed method can be used to segment the bladder region and give faster convergence compared to the active contour snake method. To conclude, the calculation of depth, area, and volume of bladder is successfully done using MATLAB. In the future, this work could be extended to high-level image processing such as processing in real-time applications.

References

1. Maroulis, D.E., Savelonas, M.A., Karkanis, S.A., Iakovidis, D.K., Dimitropoulos, N, "Variable Background Active Contour Model for Computer-Aided Delineation of Nodules in Thyroid Ultrasound Images" 18th IEEE Symposium of Computer-based Medical System, 2005, pp. 271–276.
2. M. Fa.Gerquist, U. Fa.Gerquist, A.Ode. N and S. G. Blomberg, "Estimation of fetal urinary bladder volume using the sum-of-cylinders method vs. the ellipsoid formula" Ultrasound Obstet Gynecol 2003; 22: 67–73 Wiley InterScience.
3. Slappendel R, Weber EW, "Non-invasive measurement of bladder volume as an indication for bladder catheterisation after orthopaedic surgery and its effect on urinary tract infections" Eur J Anaesthesiol 1999.
4. Lankton, S.; Tannenbaum, A, "Localizing Region-Based Active Contours". IEEE Transaction on Image Processing, 2008, 17(11), pp. 2029–2039.
5. J Dudley et al, "Clinical agreement between automated and calculated ultrasound measurements of bladder volume", pp. 832–834 The British Institute of Radiology, 2003.
6. T. F. Chan and L. A. Vese, "Active contours without edges", IEEE Transactions on Image Processing 2001, pp. 266–277.