

Application Of Quad-Split Technique Over Edge Segmented Ultrasound Image To Find The Area And Volume Of The Urinary Bladder

¹B. Padmapriya*, ²T. Kesavamurthi

¹Assistant Professor, Department of Biomedical Engineering, PSG College of Technology, Coimbatore

²Assistant Professor (Sr.Gr) Department of Electronics and Communication Engineering, PSG College of Technology, Coimbatore

Abstract

The novel technique that the paper presents 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. This method makes use of traditional Hough transform over the preprocessed image to link the discontinuities present in the segmented image which is obtained in the subsequent stages of processing. Experimental results show good performance of the proposed model in segmenting urinary bladder to measure its exact area and volume.

Keywords — Image segmentation, Hough transform, Urinary bladder

1. Introduction

In an image only certain parts consist of useful information which is rendered as the area of interest. These parts are frequently referred as a target. They generally correspond to the image in a specific and unique nature of the area. It needs to be extracted and separated in order to identify and analyze the object or the area of interest. Image segmentation is a technique which divides the image into different regions and extracts out the interested target.

Image processing gives emphasis on the transformation within the images and improves the visual effects of image. Image analysis is mainly used to monitor and measure the interested targets in the image in order to extract information and as a result build up a description of the image.

Image segmentation is a key step from image processing to image analysis and it occupies an important place. On one hand, it is the basis of target

expression and has important effect on the feature measurement. In the actual production life, the application of image segmentation is very wide and has almost appeared in all related areas of image processing [12].

Ultrasound imaging is one of the main attractions of imaging modality due to its non-invasive characteristic and the ability to distinguish interfaces in between soft tissues. Diagnostic ultrasound is applied for obtaining images of almost all internal organs of the abdomen. The area of interest of study is the urinary bladder.

In this paper, the concept of image segmentation is effectively applied on the ultrasound image and the proposed algorithm for the measurement of area and volume is implemented.

The calculation of area and volume helps us to detect abnormalities like variation of the bladder thickness, asymmetry of the bladder, cystic mass within the bladder, solid mass within the bladder or at the base of the bladder and determines the extent of the abnormality.[11]

2. Existing Methodology

At present the area and volume of the bladder is obtained by a trackball arrangement. Here the operator marks points over the boundary manually. The marked points are approximated into an ellipsoid 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 of the ellipsoid is calculated from the following formula.

$$\text{Volume of ellipsoid} = \frac{\pi}{6} * (a * b * c) \quad (1)$$

Where,

a is the length of the major axis

b is the length of the minor axis

c is the length of the vertical axis

3. Basic Steps of Pre-Processing

The steps involved in pre-processing are explained in the following paragraphs.

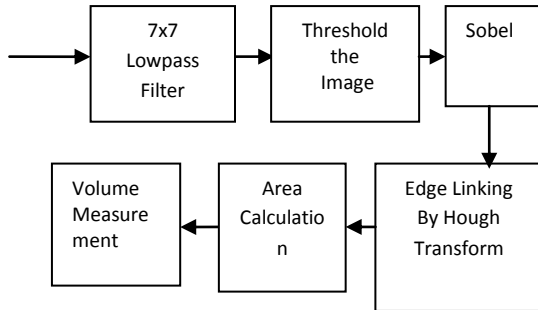


Figure.1. Block diagram of basic steps of pre-processing

Figure.1. shows the block diagram of the basic steps involved in the pre-processing.

3.1 Lowpass Filter

The lowpass filter seeks to remove unwanted noise from an image while at the same time preserving all of the essential details that an observer would wish to see in the original image. Image noise generally manifests itself as random fluctuations in grey-level values superimposed upon the ‘ideal’ grey-level pixel value, and it usually has a high spatial frequency.

The filtering operation can be implemented by convolving the entire image with a simple 7 x 7 window or mask.

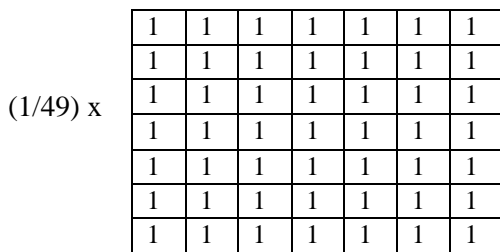


Figure.2. Low pass filter mask

The application of the lowpass filter of size was done by replacing each pixel value by the average or mean of its immediate neighbours. The averaging process has the effect of ironing out significant gray-level differences between pixels in a neighborhood. This technique reduces image noise but at the expense of

significant image blur as it tends to smear the edges of objects in the image [8].

3.2. Thresholding

Binary images are much simpler to analyze than gray-scale images, but raw images often cannot be converted directly to binary without some preprocessing. There is a special case of intensity quantization called ‘binarisation’ where an image is generated with only two gray – levels, black and white (i.e., 1=1).

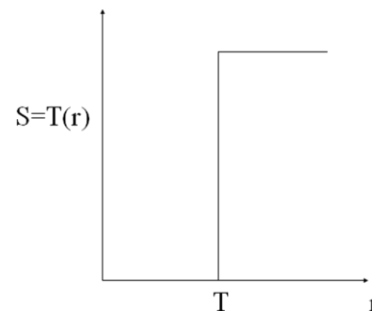


Figure.3. Thresholding Function

A threshold value, T, is used to partition the image into pixels with just two values as referred in equation 2 and 3.

$$\text{If } f(x, y) \geq T \text{ Then } g(x, y) = 255 \tag{2}$$

$$\text{If } f(x, y) < T \text{ Then } g(x, y) = 0 \tag{3}$$

Where g(x, y)-(output image) denotes the binarised version of f(x, y)-(input image)

The binary image will be highly dependent on the value of T, the threshold value.

From segmentation point of view, thresholding is a method of producing regions of uniformity within an image based on some threshold criterion T. [9]

3.2. Edge Detection

The binary images cannot be directly taken up for processing. So the edges of the image are detected by sobel operator and it is considered for further processing. The sobel operator was found having the advantage of providing both a differencing and smoothing effect [1].

Derivatives based on the sobel operator masks are given in equations 4 and 5.

$$G_x(m,n) = (Z_7 + 2Z_8 + Z_9) - (Z_1 + 2Z_2 + Z_3) \tag{4}$$

$$G_y(m,n) = (Z_3 + 2Z_6 + Z_9) - (Z_1 + 2Z_4 + Z_7) \tag{5}$$

Table I
Row Mask

-1	-2	-1
0	0	0
1	2	1

Table II
Column Mask

-1	0	1
-2	0	2
-1	0	1

Where, as before, the Z's are the gray levels of the pixels overlapped by the masks at any location in an image. A computation of the gradient at the location of the center of the masks then utilizes the equations to find the magnitude and direction, which gives one value of the gradient.

Thus, after the procedure has been completed for all possible locations, the result is a gradient image of the same size as the original image.

The pixel location (m,n) is declared as an edge location if G(m,n) exceeds some threshold T. The edge map gives the necessary data for tracing the object boundaries in an image.

4. Edge Linking Through Hough transform

An improper recording of the image and also preprocessing the image can cause discontinuities in the edges. This is difficult and requires some level of reasoning about the relationship between the various pieces of the boundary. [4]

If the edges are relatively strong and the noise level is low, one can threshold an edge-magnitude image and thin the resulting binary image down to single pixel-wide closed, connected boundaries. [12]. Edge linking can be established by using the Hough Transform. The main advantage of the Hough transform technique is that it is tolerant of gaps in feature boundary

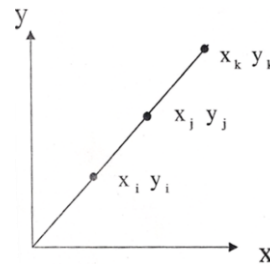
descriptions and is relatively unaffected by image noise [5].

We may attempt to fit a line in the slope intercept form; that is

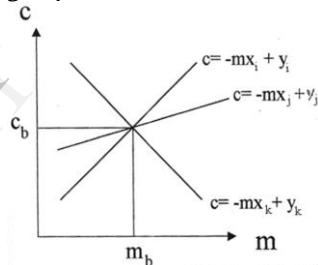
$$Y_i = mX_i + C \tag{6}$$

However, the approach as in equation 6 has two shortcomings. Vertical lines (lines with $(a = \alpha)$) are not representable and only the parameters of a single line may be determined in this manner.

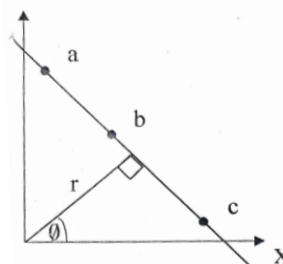
Input Space



Hough Space



Input Space



Hough Space

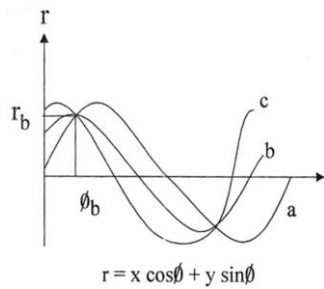


Figure.4. Hough Transform

One problem with this approach is that when implemented in discrete digital form, a very large array of hough space 'accumulators' is required to store all possible votes since the range of values should extend from minus infinity to infinity.

To overcome these shortcomings, we instead choose the normal form for line representation; that is; a line is represented by the parameters (r, ϕ) as shown in equation 7.

$$r = X_i \cos \phi + Y_i \sin \phi \quad (7)$$

The range of ϕ is $+90$ or -90 with respect to x -axis. Any point (X_i, Y_i) on a line determined by (r, ϕ) will be constrained by the above equation, which represents a point-to-curve transformation. Thus, from the straight line version of the hough transform r - ϕ space, it is possible to show that any common point (i.e., intersection) of the r - ϕ curves for two points determines the parameters of a line concept to the case of three collinear points; the r - ϕ curves for these lines share a common point (r, ϕ) , which represents the normal form characterization for this 3-point line. Therefore, if we generate the n r - ϕ curves for all points in the given set, points of intersection of large number of curves present strong evidence that a line should be fitted to these points. Moreover, these specific points in (r, ϕ) space are the line parameters. The hough approach therefore yields both as an indicator of the number of lines and their parameters. Actual computer implementation of the r - ϕ curve calculation and recording of intersections involves discretization of 2-D r - ϕ space into finite intervals or 2-D "bins". Each of these bins in r - ϕ space is an accumulator, which is initialized to zero. The discretized r - ϕ curves are generated and each bin that lies along a specific r - ϕ constraint curve is augmented by one to indicate membership in this possible solution curve. Resulting peaks in the (r, ϕ) accumulator array indicate strong evidence of lines in the image. The peaks beyond a particular threshold (h_{th}) are selected for edge linking in the x - y plane. After linking the discontinued edges, the area should be calculated.

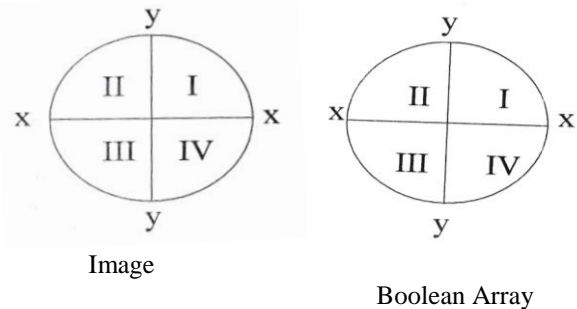
5. Area Calculation

A novel algorithm is developed for calculating the area of the urinary bladder.

The area of the urinary bladder is found by dividing the image into four quadrants and then adding the total number of pixels in each quadrant. A Boolean array is used in order to avoid recounting of pixels by changing the corresponding value for each counted pixel in the image. Each pixel counted is assigned a large value to show the operator the confined area of calculation.

The code for area calculation is provided in a function which is called for by the main program. The main program decides the coordinates of the center point of the quadrants in the function. A loop for the x -value from the centre point of the quadrant to the right extreme, incremented in steps of one is initialized. If a particular x -value has pixel intensity 0, then a loop in the y -direction from the centre of the quadrant to the upper extreme that counts the number of black pixels and changes the corresponding Boolean value to TRUE, until it reaches a pixel with high intensity is initialized. The above iteration is repeated till the loop in the x -direction encounters a pixel with high intensity.

For cross-checking, the above process is repeated by initializing the loop in the y -direction from the centre to upper extreme and scanning along the x -axis till a white pixel is reached, for every increment in y . If we scan a black pixel and its corresponding Boolean value is FALSE, then, we assign it TRUE after adding it to the total count. The counted +black pixel is assigned a large value for visualization. The above iteration is done till a white pixel is encountered.



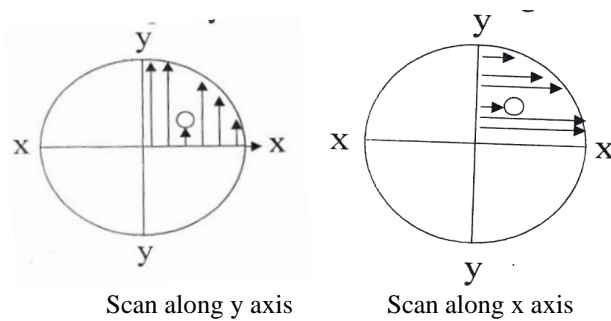


Figure.5. Area Calculation Method

5.1 Conversion to Real Time Unit

After finding the total number of pixels in the scan image, it should be converted into the real time unit. The company for which this methodology was implemented had given a constant value of 200 for conversion purpose. The value is decided based on the camera present in that machine and the resolution of the picture obtained out of it. The value obtained after counting the total number of pixels is to be divided by the constant value 200 will give the area of the urinary bladder [3].

6. Volume Measurement

The area measurement when combined with the value obtained from the sagittal scan gives the volume of the bladder.

The value obtained from the sagittal scan is equivalent to the width of the urinary bladder which is divided by 2 and then multiplied by a constant 0.625 or $(\pi/6)$. The resultant value is multiplied by the area value obtained to give away the result of the volume of the urinary bladder. As per radiologist's reference, the tolerance limit could be $\pm 50 \text{ cm}^3$ from the existing method.

7. Results and Discussions

The proposed algorithm is tested for various ultrasound bladder images successfully and appreciable results were obtained for the samples. The various results obtained are thus shown from figure 6-11.

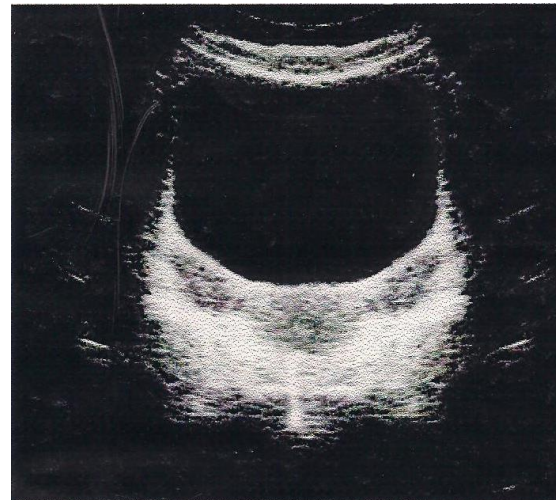


Figure.6.Original Ultrasound Urinary Bladder Scan Image

The Figure.6.shows the ultrasound bladder scan image of size 256x256x8 of gray scale. This is considered to be the original image taken up for processing.

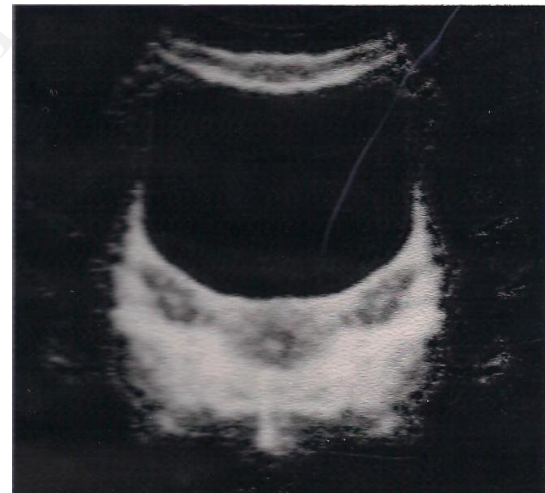


Figure.7. Low pass filtered image

The Figure.7.shows the image after applying the lowpass filter mask of size 7x7 on to the original image. The noises are removed and it results in the blurring of the image



Figure.8.Thresholded image

The Figure.8.shows the binarised version of the lowpass filtered image which will be easier to do further processing.

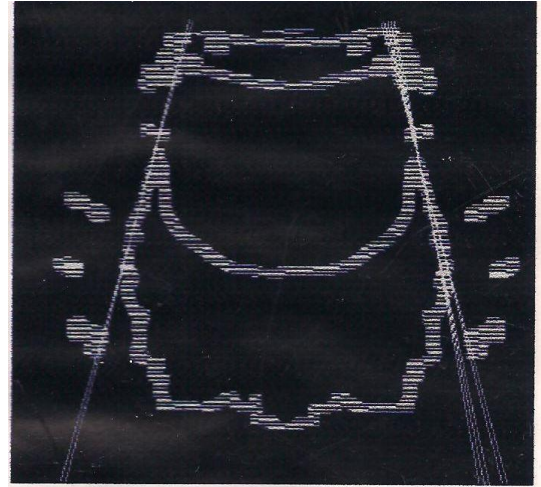


Figure.10.Edge linked image

The Figure.10.shows the discontinuities in the edges of the urinary bladder scan that is linked by hough transform technique.

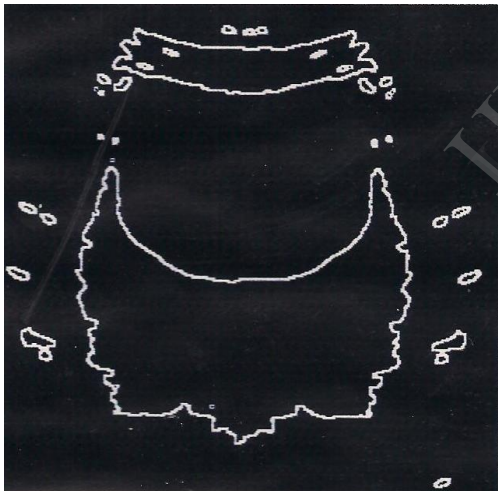


Figure.9.Edge detected image

The Figure.9.shows the application of Sobel gradient operator over the thresholded image to extract the edges.

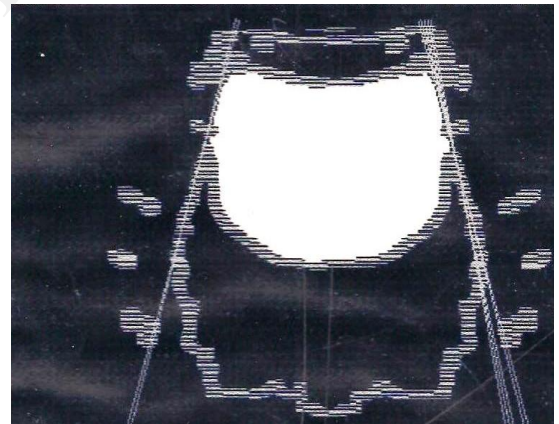


Figure.11.Area of the bladder

The Figure.11.shows the area of the bladder found out in terms of total number of pixels and it is being converted to the real time unit by dividing it by a constant 200 to give the area of bladder in terms of cm^2

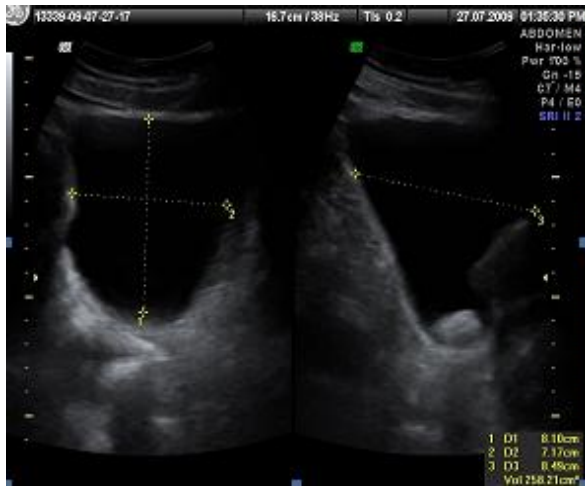


Figure.12. Volume measurement.

The Figure.12.shows the result of the existing methodology and the result is 258.21 cm^3 . Assuming the area of the bladder is 80 cm^2 . The value obtained from the sagittal scan is 4.24 which is being multiplied by .625 which is then multiplied by 80 cm^2 to give away the volume of urinary bladder as 212 cm^3 . (The tolerance limit is $\pm 50 \text{ cm}^3$ from the existing method).

7.1 Comparative Results

Table III

EXISTING METHODOLOGY in cm^3	PROPOSED METHODOLOGY in cm^3
258.21	212
272.3	245.76
268.9	243.2
256	276.4
243.8	258.4

8. Conclusion

The proposed method is novel and very much reliable in terms of the accuracy of the results. Also it is easier to implement and use, hence reducing the human error while tracing the boundary which may lead to an erroneous result [3]. It also helps in reducing the computational time for diagnosis being fully automatic. Thus this method is relatively superior in all terms compared to the conventional techniques available.

Acknowledgment

We would like to extend our thanks to **Dr.S.Arunkumar**, Radiologist, Kovai Medical Centre and Hospital, Coimbatore, for his valuable guidance towards the completion of the paper.

References

1. G Z Yang and D F Gilles, 1990. Image Processing and Edge Detection, Department of Computing, Imperial College
2. Rajwinder Kaur and Monika Verma. et al., 2002 Classification of various edge detectors, Department of Computer Science, RIEIT, Railmajra
3. N J Dudley, M. Kirland. et al., 2003. Clinical agreement between automated and Calculated Ultrasound measurements of bladder volume, *The British Journal of Radiology*
4. D H Ballard., 1980. Computer science Department, Rochester, Newyork, U.S.A., Generalizing the Hough transform to detect Arbitrary shapes
5. E Duquenoy and A Taleb-Ahmed., 2006. Applying Hough transform pseudo-linearity property to improve Computing speed, *Elsevier Science Inc*, Vol-27, Issue 16, Pgs -1893-1904.
6. H.Chidiac and D.Ziou., 1999. Classification of Image Edges, *Vision Interface '99, Troise-Rivieres, Canada*.pp. 17-24.
7. P. Hua, E. J. Woo, J. G. Webster, and W. J. Tompkins. Bladder fullness detection using multiple electrodes. *Engineering in Medicine and Biology Society, 1988. Proceedings of the Annual International Conference of the IEEE*, 1988.
8. F. M. Waltz, G. W. Timm, and W. E. Bradley,"Bladder volume sensing by resistance measurements,"*IEEE Trans. Bio-Med. Eng.*, vol. 18, pp. 42-4&, Jan. 1971.
9. Hwang JY, Byun SS, Oh SJ, Kim HC. Novel algorithm for improving accuracy of ultrasound measurement of residual urine volume according to bladder shape. *Urology*. Nov;64(5):887-91,2004.
10. LS Marks, FJ Dorey, ML Macairan. Three dimensional ultrasound devices for rapid determination of bladder volume. *Urology*, 50(3), pp.341-348, 1997.
11. GM Coombes, RJ Millard. The accuracy of portable ultrasound scanning in the measurement of residual urine volume. *The Journal of Urology*, 152, pp.2083-2085, 1994.
12. P Schnider, P Birner, A Gendo, K Ratheiser, E Auff. Bladdervolume determination: portable 3-D versus stationary 2-D ultrasound device. *Arch Phys Med Rehabil 81*, pp 18-21, 2000.