Comparison of Histogram Thresholding Methods for Ultrasound Appendix Image Extraction

Milton Wider, Yin M. Myint, Eko Supriyanto

Abstract – Ultrasound image can facilitate the physician to identify the cause of an enlarged abdominal organ. This paper presents the attempt to diagnose the appendicitis by extracting appendix from abdominal ultrasound image. Histogram thresholding methods are compared for the appendix extraction. Moreover, the performance changes of appendix extraction methods in according with the position of scanning probe are presented. In order to segment out the appendix from ultrasound image, this paper discusses the comparative results of three thresholding segmentation methods. From this comparison it can be clearly seen that the proposed method is the most appropriate method for appendix image segmentation. When analyzed the extracted appendix image, it can be concluded that the normal probe view is the best transducer position.

Keywords – appendix image, extraction, histogram thresholding, probe view, transducer position.

I. Introduction

CT-SCAN has been found more reliable to be used for appendicitis diagnosis in pregnant patient, however the radiation exposure during the diagnosis double the risk to develop a fetal abnormalities which in turn makes ultrasound screening as the preferable method to examine on appendicitis in pregnant patient [2]. However, a study for ultrasound screening in 33 pregnant patients shows 88% failure on detecting the pathologically proven having appendicitis. A study to compare MRI and ultrasound screening on reliability to detect appendicitis shows that MRI correctly diagnosed 33 of 34 cases (97%) of acute appendicitis compared to ultrasound screening [2]. So ultrasounds screening correctly diagnosed appendicitis lower than MRI [3].

However, ultrasound is a nonionizing method for scanning which is very useful for pregnant patient. Hence, the poor ability of ultrasound to find appendicitis is solemnly the limitation of the ultrasound screening hardware itself. Upgrading parts, system and hardware might help to enhance the detection for organs inside the body.

Apart from that, nonvisualized image when examined can be counterattacked by image processing. Clearer image can be obtained by exploring some image processing methods on the blurry image which in turn can help in better visualization for accurate diagnosis and interpretation by the specialists or medical doctors.

This paper describes the enhancement of medical ultrasound images mainly for appendicitis. This can be achieved by examining some methods on image processing. They are:

1. image segmentation
2. image enhancement and
3. parameter measurement.

For medical segmentation purpose, various thresholding methods have been used. This paper presents the analysis of thresholding methods for appendix image. Averaging noise filtering 3X3 kernel method has been implemented for image enhancement. Finally, image labeling and area pixel selection method are used for parameter measurement.

The appendix is an appendage or appendix like structure. It is a wormlike intestinal diverticulum extending from the blind end of the cecum; it varies in length and ends in a blind extremity [7].

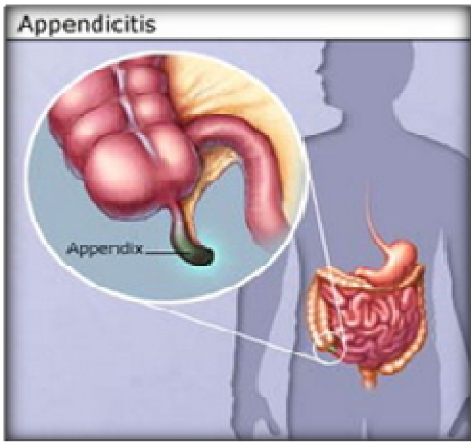

Fig. 1 Anatomy of appendix

The appendix is part of the cecum from which it originates where the 3 tenia coli coalesce at the distal aspect of the cecum. Not surprisingly, the appendix resembles the cecum histologically and includes circular and longitudinal muscle layers. The appendix arises from the cecum approximately 2.5 cm below the ileocecal valve. It varies in length from complete agenesis to more than 30 cm, but it is usually 5 to 10 cm in length. The mean width is 0.5 to 1.0 cm [6].

The main thrust of events leading to the development of acute appendicitis lies in the appendix developing a compromised blood supply due to obstruction of its lumen and becomes very vulnerable to invasion by bacteria found in the gut normally. Obstruction of the appendix lumen by faecolith, enlarged lymph node, worms, tumour, normal mucus secretions continue within the lumen of the appendix or indeed foreign objects, brings about a raised intra-luminal

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pressure, which causes the wall of the appendix to become distended, thus causing further build up of intra-luminal pressures [8].

(a) (b)

Fig. 2 (a) normal appendix (b) appendix inflammation

By using ultrasound to diagnose appendicitis, visualizing still remains a difficulty. A normal appendix is hard to be detected in ultrasound image so any visualize appendix in ultrasound image is considered as abnormal [9]. The same evaluation is true for the patient with obese.

In this paper, two image processing methods will be discussed namely image segmentation and noise filtering methods. Image segmentation frequently used to aid in isolating or removing specific portions of an image. Some examples for image segmentation are graph cuts, normalized cuts, and mean shift [10]. Denoising or noise filtering method can be categorized into two types. They are linear filtering and nonlinear filtering. Example of linear filtering is mean filter and LMS adaptive filter whereas the example for nonlinear filter is median filter [10].

The graph cuts method is good for medical and scientific imaging where very specific items from many images are being looked to segment. The normalized cut method and mean shift method are both better suited for automatic segmentation. Both can achieve an over-segmentation of the image into "super-pixels" or a segmentation that divides the image into only a few main regions, hopefully picking out the main objects [10].

From the experimental and mathematical results [11],[12],[13] it can be concluded that for salt and pepper noise, the median filter is optimal compared to mean filter and LMS adaptive filter. It produces the maximum SNR for the output image compared to the linear filters considered. The LMS adaptive filter proves to be better than the mean filter but has more time complexity. From the output images, the image obtained from the median filter has no noise present in it and is close to the high quality image. The sharpness of the image is retained unlike in the case of linear filtering.

Among them histogram thresholding method for image segmentation and median filter method for image noise filtering are experimentally tested and discussed in this paper. Based on the faster time in the process of obtaining the output and the ability to obtain clearer image in medical aid for better evaluation, this selection was made.

II. MATERIAL AND METHODS

A. Image/Data Collection

Appendix ultrasound images with five different probe positions are taken using Aplio MX, Toshiba ultrasound machine available in the lab.

B. Selection of Histogram Thresholding Method

The first step of this process is an attempt to choose the thresholding method. The methods tested in this approach are Otsu's thresholding method and Adaptive thresholding method and the proposed method.

Otsu's Thresholding method

Segmentation using Otsu's thresholding method is based on region homogeneity which can be measured using variance. Otsu's method selects the threshold by minimizing the within-class variance or maximizing between-class variance.

The variance of the image with L gray levels is calculated from

$$\sigma^2 = \sum_{i=1}^{L} (i-\mu)^2 P(i) \,. \tag{1}$$

Where *P(i)* is the normalized frequency for each gray level value i and μ is the mean gray level value over the whole image and calculated as:

$$\mu = \frac{\sum_{i=1}^{L} iP(i)}{\sum_{i=1}^{L} P(i)} = \sum_{i=1}^{L} iP(i) \,. \tag{2}$$

Since the total variance σ is independent of T, the value of T minimizing σ_W^2 will be that of T maximizing σ_B^2. Where σ_W^2 is within class variance and σ_B^2 is between class variances. Between class variances can be calculated from (3) below.

$$\sigma_B^2 = \frac{[\mu(T) - \mu q_B(T)]^2}{q_B(T) q_O(T)} \,. \tag{3}$$

Where $q_B(T)$ and $q_O(T)$ are the fractions of pixels for the region classified as background and object. Then T is determined by finding the gray laevel values which causes the maximum between class variance. The matlab code: " t=graythresh(x);"computes the global threshold value *T*. Where x is the grayscale appendix image.

Adaptive Thresholding Method

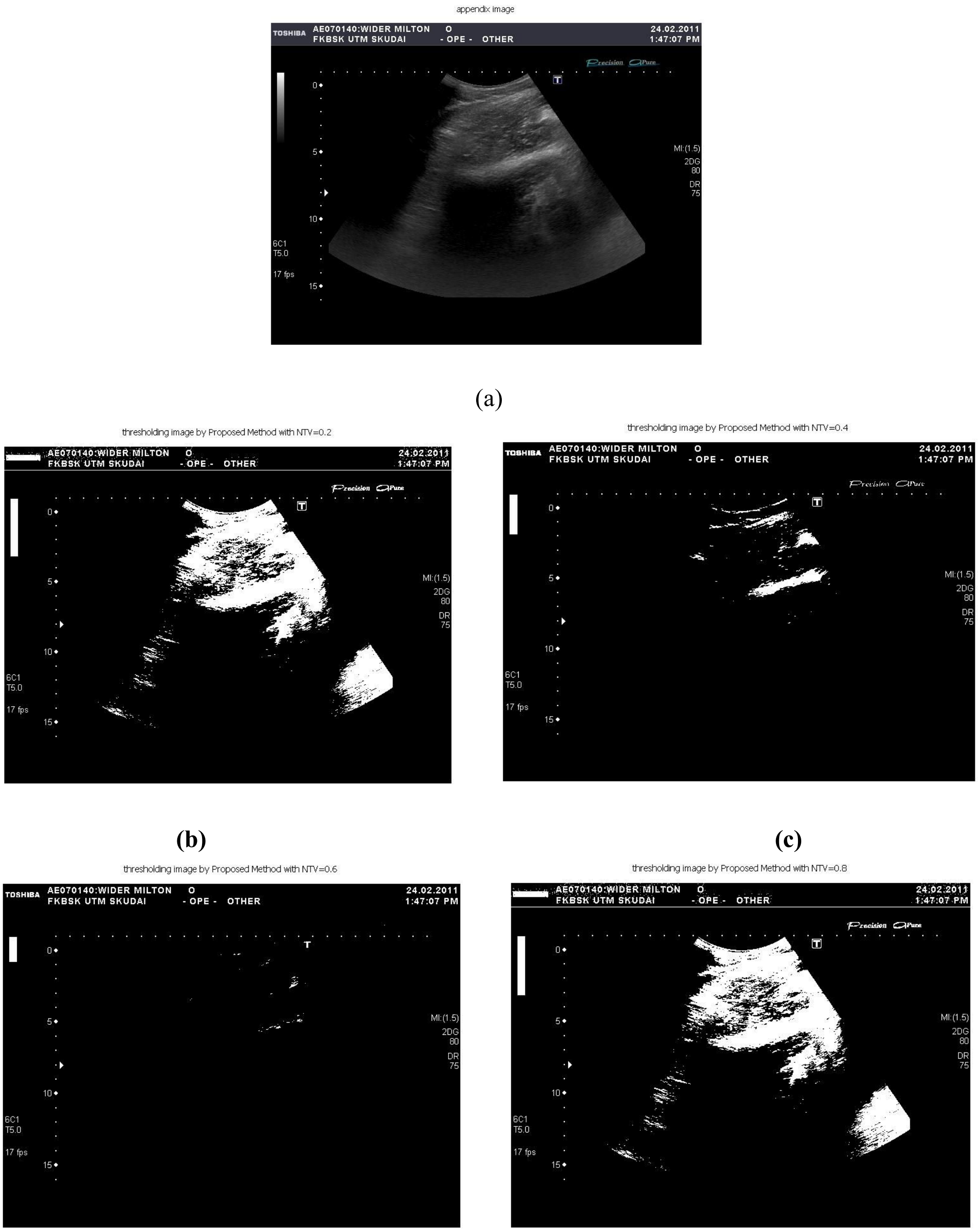
The global threshold technique is used to segment the pixels into either white or black using a predefined value, adaptive threshold is used to separate preferred objects in the foreground from the background [14]. The algorithm of adaptive thresholding discussed in this paper is developed as follows.

Step 1. Read the input image.
Step 2. Set error=1.
Step 3. Set initial T0.

Step 4. Set u1=u2=cnt1=cnt2=0.
Step 5. IF grayscale level of current pixel < T0 THEN
        u1=u1+ gray level of current pixel;
        cnt1=cnt1+1;
    ELSE
        u2=u2+ gray level of current pixel;
        cnt2=cnt2+1;
Step 6. Loop step 5 until the last pixel.
Step 7. Calculate
        u1=u1/cnt1;
        u2=u2/cnt2;
        T=(u1+u2)/2;
        error=abs(T-T0);
Step 8. IF error > 0.0001 THEN
    GOTO Step 4

Proposed Method

The proposed method defines the threshold level by multiplying the maximum gray level of the image with the normalized threshold value. This value is within the range of 0 to 1. The comparisons of thresholding image results with various normalized value is shown in Fig. 3. Compared to the results seen in this figure, the normalized threshold value of 0.2 is chosen for the discussed work.



(a)

(b) **(c)**

(d) **(e)**

Fig. 3 (a) Original appendix image, thresholded image results by proposed method with normalized threshold values: (b) 0.2, (c) 0.4, (d) 0.5 and (e) 0.8

Comparisons of Thresholding Methods

In order to choose the proper thresholding method for appendix segmentation, this comparative study has been done. The performance of these three methods in appendix image segmentation can be seen in Table1.

From Table I, the segmentation performance of each method can be seen clearly. Each method is tested with the various appendix image scanned with the various positions of ultrasound transducer. From these test results described in Table I, it can be concluded that the proposed method in this paper is the most appropriate to segment out the appendix image. But when carefully examined the result image, it can also be seen the performance changes according to the transducer position. When considering in execution time of each method, the proposed method obviously takes the medium time. Although the performance of adaptive method and proposed method are not quite different according to the visual results, the adaptive method takes the distinct longer time as shown in Table II. So, the proposed method is selected to continue the appendix extraction from abdominal ultrasound image.

Table I. Comparison of Thresholding Methods for Appendix Segmentation

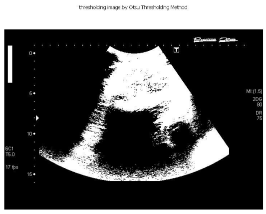
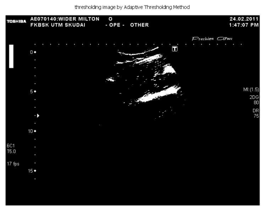
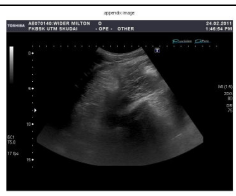
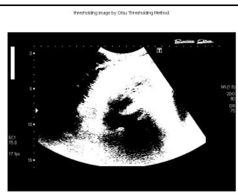
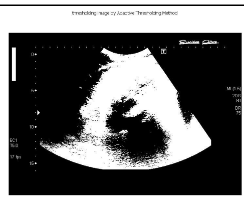
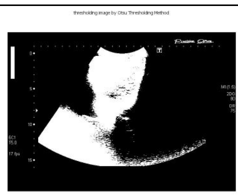
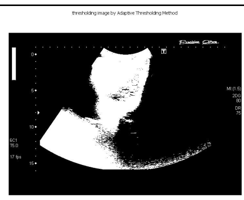
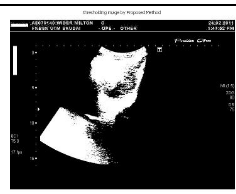
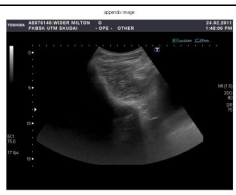
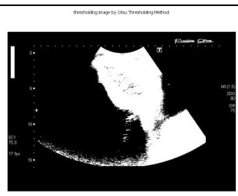
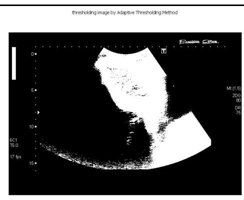
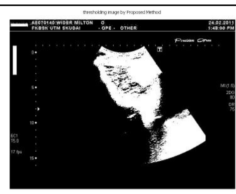
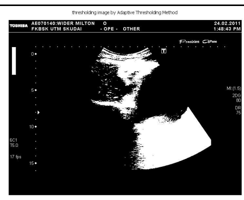
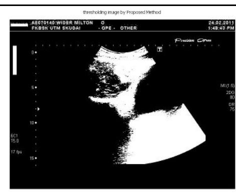
Probe View	Appendix Image	Otsu's Method	Adaptive Method	Proposed Method
Normal View				
45° Probe View				
90° Probe View				
135° Probe View				
225° Probe View				

Table II. Execution Time Comparison of Thresholding Methods

Image	Proposed Method	Otsu's Method	Adaptive Method
Normal View	0.2591 seconds	0.1987 seconds	42.1934 seconds
45° Probe View	0.1996 seconds	0.1874 seconds	82.3684 seconds
90° Probe View	0.1723 seconds	0.1765 seconds	56.3167 seconds
135° Probe View	0.1667 seconds	0.1728 seconds	60.2511 seconds
225° Probe View	0.1695 seconds	0.1619 seconds	33.7608 seconds
Comparisons	Median	Shortest	Longest

C. Process Flowchart

Fig. 4 shows the overall process implementation in this paper. First of all, the medical image of appendix is loaded to the matlab workspace. Then, the image is converted to grey scale image. This is useful if colors are present in the medical image. This is also to make the image to be easily processed later on. After that, showing the medical image and histogram is optional. This is just to see the effect done to the image by the function earlier and can be neglected if needed. The next step is to do image segmentation using histogram thresholding. This is to divide the image into its constituent region or object. Next, median filter is performed. This step will filter the noise so that the image is clearer. Finally, measurement can be done to calculate the appendix parameter using some formula and the result can be displayed. The step by step process results are described from Fig. 5 through Fig. 9.

Currently, there is no effort in image enhancement for appendicitis ultrasound image. This is due to the availability of other medical screening that can replace ultrasound which in turn can give more satisfy result as well as higher probability on positive appendicitis detection. However, using ultrasound is still the preferable methods to use for appendicitis detection for its nonionizing feature which suitable for all age, gender and physical limitations. Hence, the limitations can be counteracted by doing some image processing on the medical images which are being done in this study.

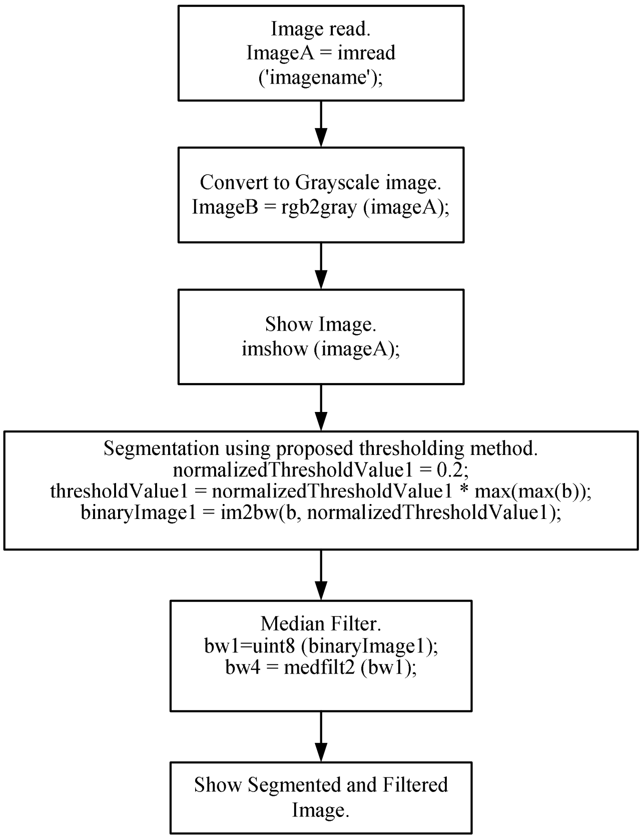


Fig. 4 Process Flow Chart

Fig. 5 illustrates the ultrasound image read by MATLAB®. That is the raw image and the appendix cannot be seen clearly.

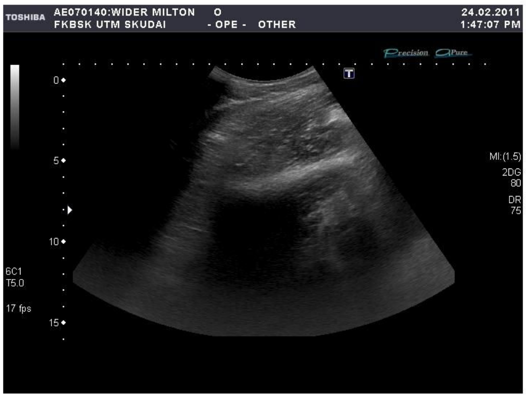


Fig. 5 Appendix Image

Fig. 6 shows the image after thresholding. Here the normalized threshold value is set as 0.2 and the proposed method is used for region based segmentation.

Fig. 6 Thresholded Image

After segmenting the image, median filter methods will be used to filter the noise that presence inside the image and obtain noise free image. Then Canny method is used to find the edges. The resulting edge detected image is described in Fig.7.

Fig. 7 Edged Detected Appendix Image

To select the desired area in region crop, labeling all pixels in the image is needed to be done. So the next process is to label in segmented image and the result is depicted in Fig. 8.

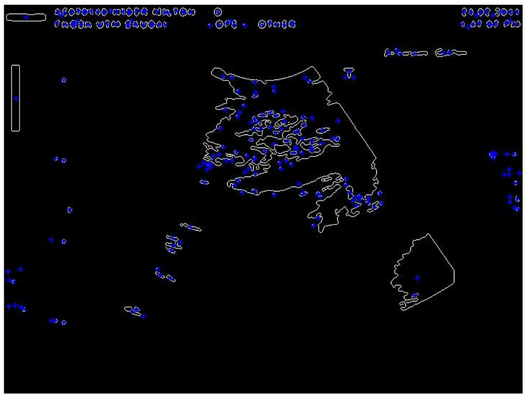


Fig. 8 Labeled Image

The last step in this process is parameterizing. In this step the appendix is lastly extract from the ultrasound image. The result can be seen in Fig. 9.

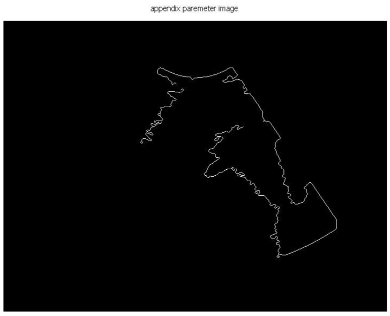
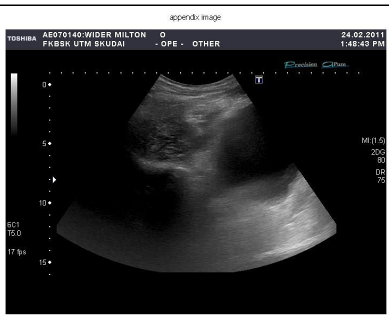
Fig. 9 After parameterising Labeled Appendix Image

III. RESULT ANALYSIS

From Fig. 5 through Fig. 9, it can be said that the implemented process can detect clearly the outline of the appendix. This can make the evaluation easier by calculating the distance of the appendix. However the whole appendix cannot be detected. Some region of the appendix had been cut off due to the discontinuity of the pixel in the image after edge detection. This may be due to the poor image quality that captured by the ultrasound and inappropriate use of probes when examining, which in turn gives a low quality and blurry image. These factors highly affected the image.

This process is tested with the appendix image scanned with various probe view. These test results are described in Table III.

Table III. Result Analysis According to Transducer Position

Probe View	Appendix Image	Result	Remark from visual result
Normal View			Appendix is detected.
45° Probe View			Appendix is not detected.
90° Probe View			Appendix is not detected.
135° Probe View			Appendix is not detected.
225° Probe View			Appendix is not detected.

From the visual results described in Table III, it can be stated that the performance of appendix image extraction method discussed in this paper wholly depends on the scanning transducer position. Moreover, it can be recommended that if a better quality of image is used, a more satisfying output result could be achieved.

IV. CONCLUSION

A new approach on ultrasound appendix image processing using image segmentation and image enhancement has been developed. The project successfully enhances the medical ultrasound image mainly for appendicitis. This is achieved by examining the methods specified on image processing namely medical image segmentation, image enhancement and parameter measurement

The result shows the detection of the appendix in ultrasound image. The outline of the appendix is clearly seen at the end of the process but it depends on the probe view. From these results, the proposed method can extract the appendix more clearly than other two methods. The dependency of the performance on the probe position also described and it can be concluded that the normal probe view is the most appropriate transducer position to get the better result.

V. FUTURE EXTENSION

This attempt emphasizes on the histogram thresholding methods for segmentation of appendix image. As for the enhancement of appendicitis diagnosis algorithm, other segmentation methods will be tested and compared and chosen for the best algorithm. The discussed method can extract even a normal appendix, which is difficult obviously.

This method can be used on other application not only on appendix but also on the application for iris identification recognition and tumor recollection or detection. Whereby the iris can be outlined with this method to indicate it's parameter for identification recognition. This is also applicable to the tumor detection where the tumor too can be outlined with this method for better evaluation by the examiner on the tumor location.

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