Edge Detection and Diameter Measurement of Appendiceal Ultrasound Images for the Assessment of Acute Appendicitis

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Abstract: - Acute appendicitis is one of the most common surgical emergencies worldwide. Accurate confirmation of appendicitis either clinically or by ultrasonography (US) evaluation is essential for early treatment. In current clinical practice, the measurement of the outer appendiceal diameter by sonographers has been used to confirm acute appendicitis. Thus, certain image processing can be used to enhance the image quality to help sonographers in performing a better diagnosis. This paper proposed a series of image processing method including image thresholding, enhancement and edge detection before measuring the appendiceal. Ten trials of measurement by sonographers using ultrasound and measurement after image processing were gathered. Statistical analyses of both measurements were computed. Mean and standard deviation for the sonographers measurements and measurements after image processing are 4.937±0.1425989mm and 4.613710±0.0839246mm respectively. Sonographers measurement showed higher variability compared to measurement after image processing thus measuring the appendiceal diameter after image processing is more reliable.

Key-Words: - kidney ultrasound, region of interest, seed point, texture analysis, morphological operation

1 Introduction

Appendix, formally called vermiform appendix is a blind-endedhollow tube structure that is attached at the end of the cecum [1, 2]. The appendix is located near the junction of small intestine and large intestine. The position of the appendix is different in each personas it is influenced by the change in position of the cecum, when it undergoes changes during development and growth [3].

An acutely inflamed and enlarged appendix or known as the acute appendicitisis one of the most common surgical emergencies worldwide and it requires prompt surgery to remove the appendix. The outer appendiceal diameter is one of the most important established cross-sectional imaging criteria in the pre-operative evaluation of the appendix. According to the literature, the optimum cut-off point of diameter measurement is still controversial[4]. The most common usedcut-off point is 6 mm. A value greater than 6 mm is considered to be a sign of acute appendicitis, anda value less than 6 mm is regarded as typical for a normal appendix[4, 5].

Hence, accurate detection of the early sign of appendicitis is clinically important for prompt treatment. Medical imaging tools such as ultrasound, computed tomography (CT) scan, magnetic resonance imaging (MRI) [6], positron emission tomography (PET) and other diagnostic tools have been used to rule out or to confirm acute appendicitis [7]. Currently, diagnostic imaging nuclear medicine (NM) for appendicitis is not explored yet.

Currently, computed tomography (CT) scan is the preferred tools compared to ultrasound and highly recommended when dealing with those patients who are obese, or have rigid non compressible abdomen, or may have complicated appendicitis such as rupture. However, for pregnant patient, the radiation exposureduring diagnosis using CT scan, double the risk to develop foetal abnormalities. This in turn makes ultrasound screening more preferable method to examine appendicitis in pregnant patient.

Ultrasound is widely used in clinical applications due to its intuitive, convenience, safety, non-invasive, and low cost. The goal of radiologic imaging is to improve the number of true positive and decrease the number of false-negative and false positive that have confounded medical practice.

However, due to low quality of image, image processing method need to be performed for better assessment of ultrasound image.

Many image processing methods are used to enhance ultrasound image in order to produce better and clearer image. The method was chosen based on the type of the image analysed and analysis to be made[8]. The image quality is affected by the surrounding noise. Hence, filtering techniques are required to remove the noise from the image. Based on previous study, MATLAB algorithm is created to enhance the ultrasound image quality by image segmentation and image enhancement methods [7]. The image was segmented using histogram thresholding and edge detection methods to enhance the quality of the image.

2 Materials and Methods

This section will discuss the overall methodology of this study. The study starts with data collection, image processing and appendiceal diameter measurement. Lastly, statistical analysis was performed to analyze the data collected.

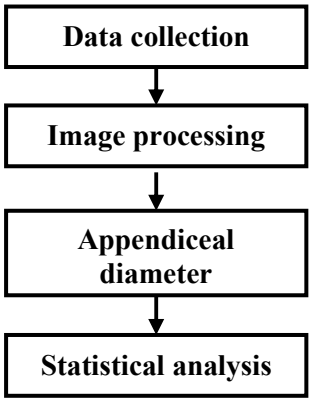

Fig. 1 Overall process of the system

2.1 Data Collection

In this study, a total of ten trials of US examination of the vermiform appendix were performed. The appendix ultrasound images were taken using Aplio MX, Toshiba ultrasound machine available in the laboratory. The type of transducer implemented in current examination is abdominal probe, with beam form 3.5 MHz frequencies. Fig. 2 shows the appendix image acquired in a coronal plane using ultrasound. The appendix is not seen clearly through the ultrasound image.

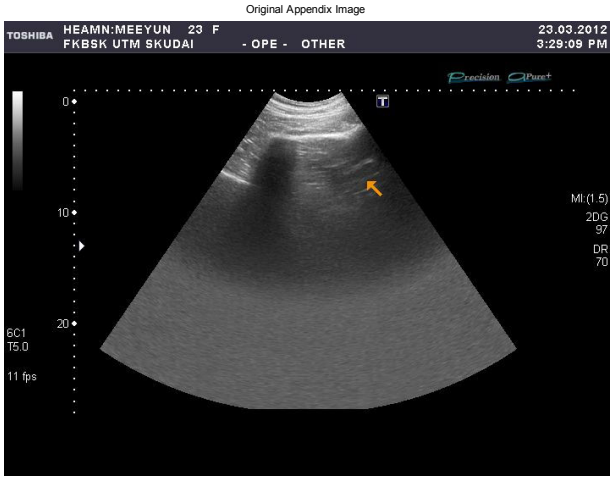

Fig. 2 Original appendix image

2.2 Image Processing

In the proposed study, ultrasound images of appendix obtained underwent a series of image processing and measurement of outer appendiceal diameter were made on the images processed using MATLAB. Fig. 3 illustrated the overall process implemented in this paper.

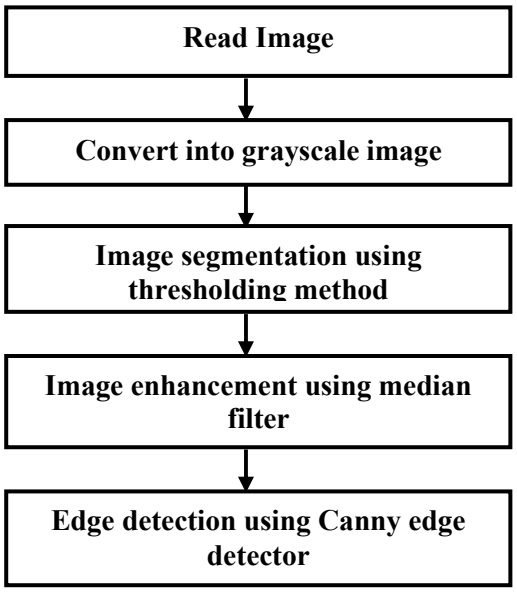

Fig. 3 Process flow chart

First of all, appendix image is loaded to the MATLAB workspace. Then, the image is converted into grayscale image. This step is important for pre-processing of the image at later stage. Next, the image is segmented using thresholding methods. This pre-processing method is to divide the image into its constituent region. The most suitable thresholding method is chosen to clearly segment the appendix in order to proceed to later works. In

order to remove unwanted noise and enhance the image quality, the median filter has been used. Edge detection method is then implemented to detect sharp edges in the image, while preserving important structural properties of the image. Lastly, manual measurement of appendiceal diameter of the appendix was carried out.

2.2.1 Image Segmentation using Thresholding Method

To clearly analyse the image of appendix, the first step is to find out the most suitable and accurate method of thresholding. 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 comparison of thresholded images with various threshold values and threshold value of 0.009 is chosen for the discussed work.

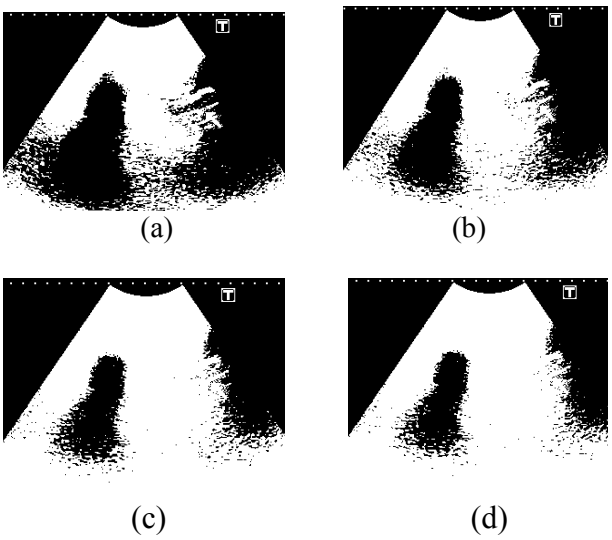

Fig. 4 Comparison of thresholded image results by proposed method with normalized threshold values: (a) 0.009, (b) 0.05, (c) 0.1 and (d) 0.4

2.2.2 Image Enhancement using Median Filter

Median filter is designed by calculating the median value of the image[9]. In median filtering, the neighbouring pixels are ranked according to brightness (intensity) and the median value becomes the new value for the central pixel. This method sorted all the pixel values from the neighbourhood into numerical order and then replacing the pixel with the middle pixel value. It removes the noise of appendix image by reducing the speckle noise and hence improve the image quality [8]. In this study, median filter is chosen to be used in image enhancement as it filtered and removed the unwanted noise in the image effectively.

2.2.3 Edge Detection using Canny Edge Detector

The process of identifying the sharp discontinuities in an image is known as edge detection [10]. Canny edge detector is mainly refers to the gathering of the pixel that have strong changes and contain the useful information of identifying[11].Canny edge detection method is a modification of Sobel method [12]. In Canny, it detected the edges by inspecting the vertical and horizontal pixel intensity[10].This method searches the edge direction by implementing non-maximum suppression to sharpen the edge. To reduce the effect of the noise during edge detection, Canny also implemented Gaussian in its method. Compared to the other methods, Canny method provide good edge detection because of its good performance in term of single response to edge.

2.3 Appendiceal Diameter Measurements

The measured parameter is outer appendiceal diameter using conventional 2D B-mode prenatal ultrasound scan protocol. In this study, the outer appendiceal diameters were measured perpendicularlyas the distance between the outer borders of the hypoechoic tunica muscularis (outer muscle coat) [13]. The ultrasound measurements were performed by the sonographer during US examination by setting the electronic callipers. For manual appendicealmeasurements, measurements were madeon processed appendix images by using MATLAB algorithm. Data obtained were then tabulated.

2.4 Statistical Analysis

Statistical analyses were performed using the SPSS 16 software (IBM SPSS Statistics). For the description of outer appendiceal diameters, baseline characteristics are presented as range, mean and standard deviation. The ultrasound and manual measurements of outer appendiceal diameter were compared in relations of standard mean error and variability.

3 Results and Analysis

This section will review and discuss on the result of each stage of image segmentation and image enhancement together with its appendiceal measurement and statistical analysis for validation purpose. Fig. 5 to 8 show the result of each step of segmentation using thresholding, enhancement

using median filter, Canny edge detection, and appendiceal measurement.

In order to clearly segment out the appendix, threshoding method is implemented. The ultrasound image is converted into binary format before segmentation. In this study, the proposed method is chosen to be used for region based segmentation. Here, the normalized threshold value is set as 0.009. Fig. 5 shows the appendix image after thresholding. The appendix is now seen clearly, but there is noise observed in the ultrasound image.

Fig. 5 Thresholded Appendix Image

After image segmentation, median filter is applied to remove unwanted noise in the image as shown in Fig. 6. The useful detail in the image is preserved and noise is successfully been reduced after filtering.

Fig. 6 Appendix image after median filter

Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. Hence, Canny edge detector is performed for edge enhancement to identify edges which then become candidates for boundaries of the image.The resulting image is displayed in Fig. 7.

Fig. 7 Appendix image after Canny edge detection

From Fig. 5 to Fig. 7, it can be seen that the implemented image processing clearly outline the appendix. This makes the evaluation easier by measuring the distance of the appendiceal diameter. 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 captured by the ultrasound and inappropriate use of probes when examining which in turn give a low quality and blurry image. These factors highly affect the quality of the image.

After a series of image processing, appendix can be visualized clearly and measurement can be made easily by MATLAB algorithm. The outer appendiceal diameters were measured perpendicularly to the long axis as shown in Fig. 8. The measurements were then tabulated.

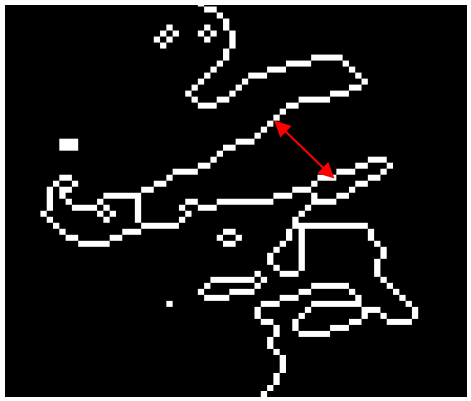

Fig. 8 Outer appendiceal diameter measurement

Measurement of outer appendiceal diameter was conducted manually in MATLAB. The results were compared to the ultrasound measurement made

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by sonographer during ultrasonography appendix examination. The data were then tabulated and analysed. From Table 1, the range of the deviation from measurements by sonoraphers are much larger compared to measurement after image processing, varies from minimum values 4.77mm to maximum values 5.16mm. Statistical analyses of sonographers measurements and measurement after image processing were computed Table 2 shows the difference of their means and standard deviations. As indicated in Table 2 above, the computed mean and standard deviation for sonographers measurements are much larger compared to measurement after image processing, which are 4.937±0.1425989mm and 4.613710±.0839246mm respectively. This revealed that sonographers measurement has higher variability than measurement after image processing. In comparison of standard error, sonographers measurement (0.0450937mm) shows greater value compared to measurement after image processing (0.0265393mm). The comparison results show a higher consistency of the measurement after image processing compared to sonographers measurement. This may be due to low quality image acquired during appendix examination. This in turn induced human error which affects the placement of calliper by sonographer during appendiceal diameter measurement.

Table 1 Summary of sonographers measurement and measurements after image processing of appendiceal diameter (mm)

No. of trial	Appendiceal diameter (mm)	
	Measurement made by ultrasound	Manual measurement using MATLAB
1	4.8100	4.6965
2	4.7900	4.5010
3	4.9800	4.5289
4	5.1300	4.7042
5	4.8500	4.6965
6	4.7700	4.5311
7	5.0700	4.6458
8	4.9300	4.6057
9	4.8800	4.5310
10	5.1600	4.6964

Table 2 Summary of statistical analysis of ultrasound and manual appendiceal diameter measurements in mm

	N	Min.	Max.	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Ultrasound_ Measurement	10	4.7700	5.1600	4.937000	.0450937	.1425989
Manual_ Measurement	10	4.5010	4.7042	4.613710	.0265393	.0839246
Valid N (listwise)	10					

4 Conclusion

Accurate appendiceal diameter measurement is essential for appendicitis early detection. It is feasible to perform a much safer appendix examination to all range of patient using ultrasound. In our study, a new approach on ultrasound appendiceal diameter measurement has been developed. This project successfully enhanced the appendix image by image processing techniques such as thresholding, noise filtering and edge detection methods. This helps in diameter measurement at later stage where the outline of appendix can be seen clearly after image processing. It can be observed that the proposed measurement after image processing has great advantages compared to sonographers measurement, in terms of its visualization and measurement consistency. Further research is necessary to standardize the image scanning angle and probe view to minimize artifacts in producing uniform images.

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