Optimization of Pancreas Measurement Techniques Based on Ultrasound Images

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Abstract: - Ultrasound imaging can be used in evaluating the acute pancreatitis, which often shows an enlarged pancreas as well as in detecting the diabetes mellitus, which the pancreas is smaller compared to normal size. Besides, these imaging techniques can be used in detecting stones in the bile duct and help in assessing the pancreatic parenchyma directly. This study proposes an approach for optimizing the pancreas measurement technique based on ultrasound images consists of image enhancement as well as image segmentation. For image enhancement, four techniques have been compared by calculating the MSE and PSNR of the output image. Level sets method has been applied for segmentation the pancreas after enhancement. This was to enable the higher accuracy of pancreas size measurement. Measurement results show that median filter gives the lowest value of MSE and highest value of PSNR compared to frequency domain Gaussian low-pass filter, histogram equalization and wavelet filter. We found that the pancreas size of Malaysian population is 8.5 ± 1.5 cm in length.

Key-Words: - pancreatic disease, acute pancreatitis, median filter, wavelet filter, pancreas size

1 Introduction

The pancreas is one of the juices and enzymes production organ located deep in the abdomen and situated behind the stomach. The enzymes produced by the pancreas help in digesting fat, protein, and carbohydrates before being absorbed by the intestine. The pancreas also produces insulin, which is important in regulating the glucose concentration in the blood. Any system dysfunction or irregularity occurs to the pancreas may lead to several diseases such as diabetes mellitus, acute pancreatitis, chronic pancreatitis, pancreatic enzyme deficiency as well as pancreas tumor.

Diabetes mellitus is a group of metabolic disorders which occurs either if the pancreas does not produce enough insulin for body usage, or if the pancreas produce enough insulin but the body cannot use the insulin it produces effectively [1, 2]. There are two types of diabetes mellitus which are Type I and Type II. Type I is an autoimmune disorder where the immune system attacks the insulin-producing beta cells in the pancreas and destroys them whereas Type II is insulin resistance condition, where the pancreas is usually producing enough insulin, but for unknown reasons, the body cannot use the insulin effectively. Pancreas, which acts as the insulin-producing gland is changed and destroyed in the process, thus leads to diabetes [3]. Study of pancreas in Type I diabetes mellitus shows significant decrease in total island mass which can be due to atrophy or decrease in growth of pancreas as the disease progresses [4]. For Type II diabetes mellitus, insulin resistance condition is due to decrease in beta cell mass [5]. Thus, diabetes mellitus will affect the pancreas size where the pancreas tends to be smaller compared to normal pancreas.

Acute pancreatitis occurs when the pancreas becomes severely inflamed and it is frequently caused by gallstone disease or excess alcohol ingestion [6, 7]. Mild acute pancreatitis is self-limiting and may not require any treatment, but up to 25 percents of patients suffer a severe attack and between 30 and 50 percents of them died [8–10]. Acute pancreatitis can be diagnosed by an elevation of the serum amylase and lipase levels. Ultrasound and magnetic resonance cholangiopancreatography can also be used in evaluating the acute pancreatitis, which often shows an enlarged pancreas. Besides, these imaging techniques can be used in detecting stones in the bile duct and help in assessing the pancreatic parenchyma directly [11].

Table 1 and Table 2 below was the result from [12], showing the ultrasound scanning results of pancreas disease. Table 1 shows the diagnostics accuracy of ultrasound pancreas scanning and according to the result, overall diagnostic accuracy if unsatisfactory scans excluded is 94/115(82%). Table 2 shows the scanning result for acute pancreatitis where based on the result, most of the pancreas with acute pancreatitis often leads to enlargement in pancreas size, besides having abnormal echoes, pseudo cysts and abscess.

Table 1: Diagnostics accuracy of ultrasound pancreas scanning

Diagnosis	**No. of patient**	**Ultrasonography diagnosis**	
		Correct	**Incorrect**
Normal pancreas	38	35	3
Acute pancreatitis	36	26	10
Chronic pancreatitis	29	21	8
Fibrocystic disease of pancreas	1	1	0
Radiation fibrosis of pancreas	1	1	0
Cancer of pancreas	10	10	0
Total	115	94	21

* In acute pancreatitis, the timing of scanning is of critical importance. Thus, in these 10 patients a normal scan might probably not indicate an incorrect diagnosis, but due to the pancreas which has already returned to normal.

Table 2: Scanning result for acute pancreatitis

No. of Patient	**Details of scan**			
	Size Increased	**Abnormal Echoes**	**Pseudo cyst**	**Abscess**
10	6	2	0	0
12	4	1	1	0
9	8	4	5	1
12	6	0	2	1
2	2	0	0	0
45	26	7	8	2

Ultrasound imaging, as a non-invasive method, plays an effective role in the evaluation of normal as well as abnormal pancreas. Many researchers suggest ultrasonography technique as the primary method of assessment of pancreatic diseases, as it is reasonably accurate, cost effective and lack of side effects [13]. Besides, pancreas location in the abdomen makes it suitable to perform diagnosis using ultrasound. However, pancreas itself has complex anatomy and it is surrounded by other organs, including the spleen, liver, and small intestine, making its interpretation of the images to become such a demanding task.

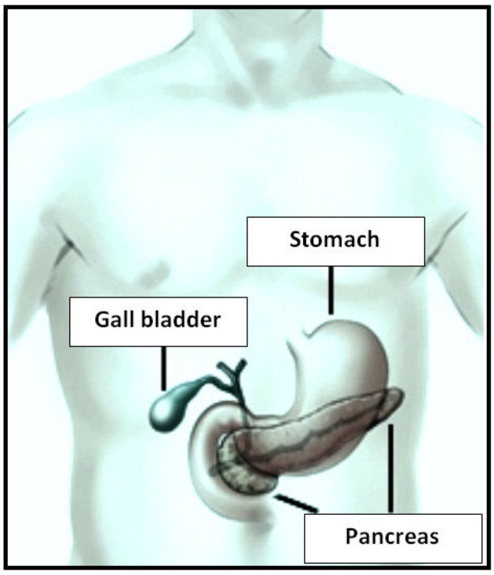

Fig. 1: Position of the pancreas in the body

In previous studies, ultrasonographic findings of pancreas were quite controversial as ultrasound images suffers from few limitations such as attenuation, speckle, shadows and signal dropout [14-17]. Thus, in analyzing the size of the pancreas, rather than just depending on the expertise of the radiographer in getting a good ultrasound pancreas images, image processing such as image enhancement and image segmentation should be thoroughly taken into consideration. Therefore, considering the size changes in pancreas in diabetes mellitus as well as in acute pancreatitis, this study was performed to find the most optimize technique for pancreas size measurement using ultrasound.

The rest of this paper is organized as follows. In section 2, we describe on the materials and the procedure of image acquisition, the characteristics of the pancreas images, image enhancement as well as image segmentation techniques performed to the pancreas images. The results and analysis of present method are shown in Section 3, and finally we draw some conclusions in Section 4.

2 Materials and Methods

In this section, we describe the procedure of image acquisition, and explain on image enhancement and segmentation methods. The images of pancreas were acquired using KONTRON (Sigma 330 Expert) ultrasound machine with a 3.5MHz convex transducer. They were saved into processing unit through our unique developed hardware in DICOM format. Then, the images will undergo image processing methods consists of image enhancement and image segmentation. In order to optimize the size measurement technique, some image enhancement techniques were compared to find the best enhancement technique for pancreas ultrasound image. The choosed technique was then been applied before the segmentation of the pancreas took place.

Fig. 2 below shows the block diagram of image acquisition from ultrasound machine to our developed hardware and Fig. 3 shows an example of pancreas image taken from a volunteer. The images from ultrasound machine were grabbed by video grabber and the images were then sent to the processing unit, controlled by I/O controller. Then, the images can be saved and displayed in the laptop for further analysis.

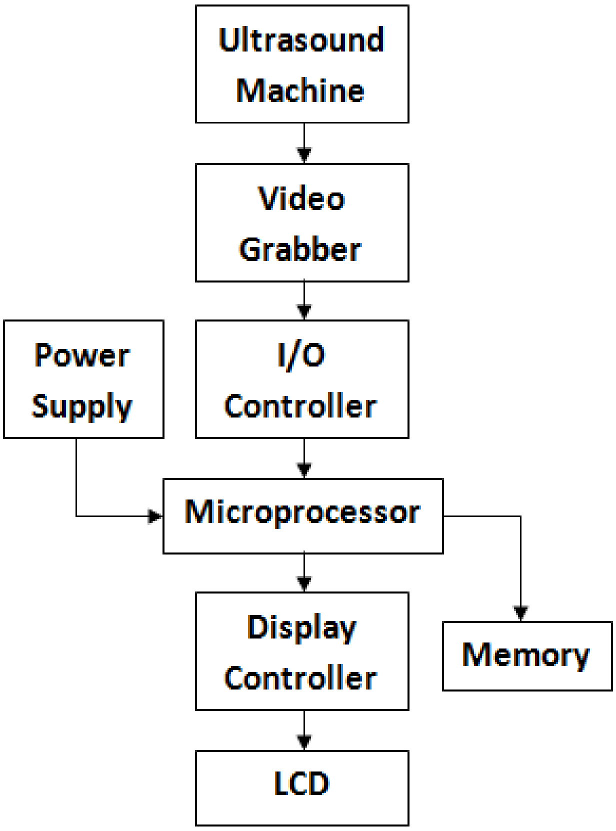

Fig. 2: Block diagram of image acquisition from ultrasound machine

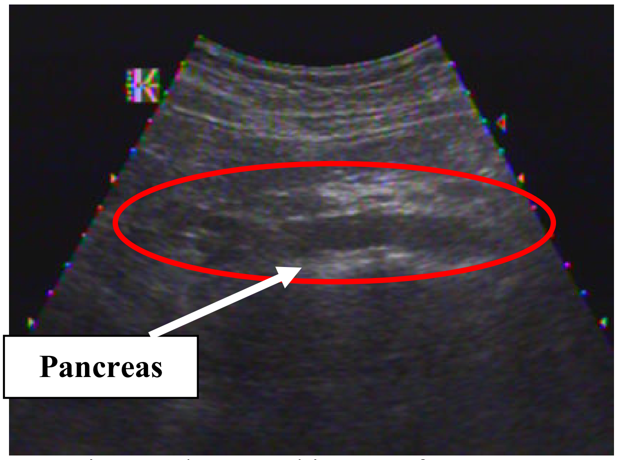

Fig. 3: Ultrasound image of pancreas

2.1 Image Processing

In this study, after the pancreas images have been stored into laptop, the image processing methods were performed. Fig 4 shows the flow chart of image processing techniques performed to the pancreas image.

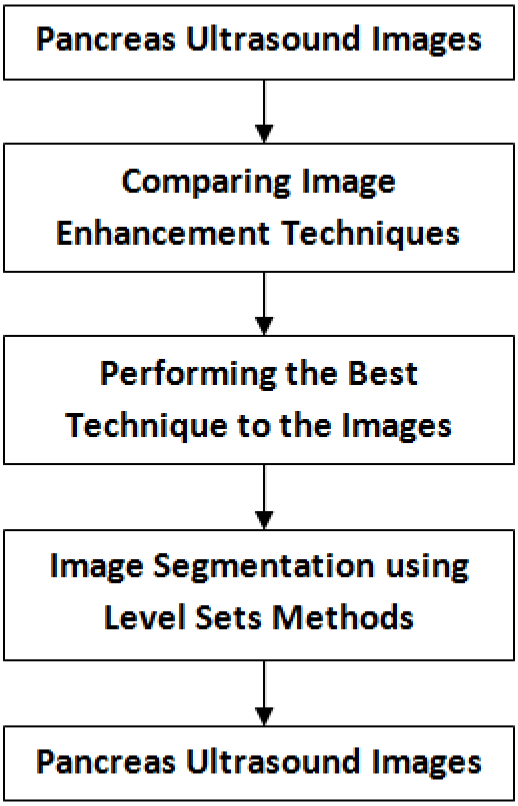

Fig. 4: Flow chart of image processing for pancreas ultrasound image

Firstly, the image of ultrasound is read into the MATLAB and changed into the gray scale image. Then, some common enhancement techniques were performed and the best enhancement method for pancreas ultrasound image was choosed before segmentation process took place. In choosing the best enhancement methods for pancreas ultrasound images, power signal to noise ratio (PSNR), and mean square error (MSE) will be calculated by comparing the enhanced images to the original images [18]. The formula for PSNR and MSE are as follows:

$$PSNR = 20\log_{10}\left[\frac{(2^n-1)}{\sqrt{MSE}}\right] \text{ [dB]} \qquad (1)$$

where n is the number of bits used in representing the pixel of the image. For grayscale image, n is 8.

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|x(i,j)-\hat{x}(i,j)|^2}{MN} \qquad (2)$$

where $x(i,j)$ is the original image, $\hat{x}(i,j)$ is the output image, and MN is the size of the image.

After being enhanced and smoothed, segmentation methods were performed. The output image of the segmentation methods was compared and the methods which segment the pancreas better was choosed. After the segmentation process, it will automatically measure the length of pancreas. Fig. 5 below shows the flow chart for finding the x_{max}, x_{min}, y_{max} and y_{min}. After automatically getting those values, the length of the pancreas will be measured.

Below is the equation to calculate the length of pancreas (L).

$$L = \sqrt{((x_{max}-x_{min})^2 + (y_{max}-y_{min})^2)} \qquad (3)$$

where, x_{max}= maximum point of X
x_{min}= minimum point of X
y_{max}= maximum point of Y
y_{min}= maximum point of Y

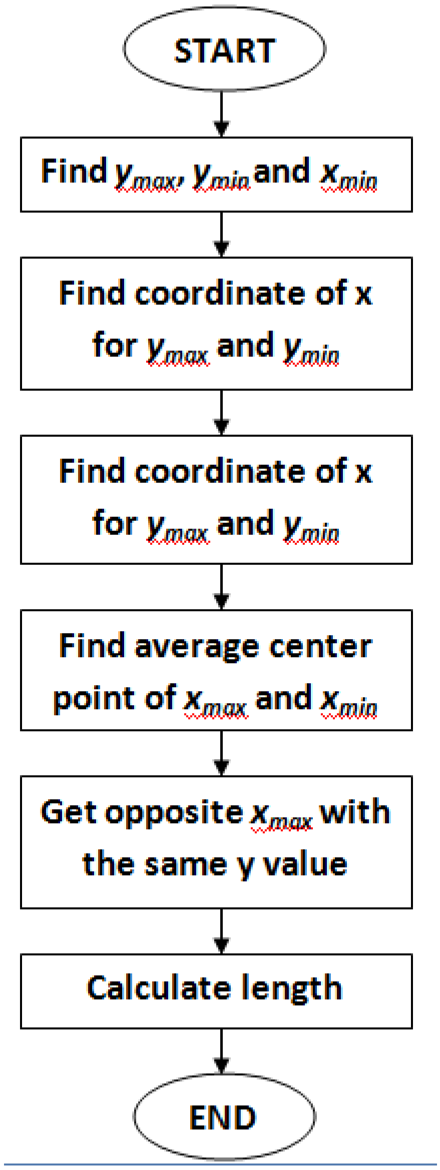

Fig. 5: Flowchart for finding x_{max}, x_{min}, y_{max} and y_{min} values

2.2 Image Enhancement

Image enhancement is one of the most important issues in low-level image processing. Image enhancement is used to improve the interpretability or perception of information in images for human viewers, or to provide `better' input for other automated image processing techniques. Many previous researches used to compare different image enhancement techniques for ultrasound images. Donoho, by decomposing the observed image into wavelet domain, present a soft-thresholding denoising method [19]. Thakur et al, by using Donoho's method, compared various wavelet filters with different thresholding values of ultrasound images [20]. Yang et al [21] used histogram matching and their experiment results show that their method can leave speckle unchanged and enhance tissue boundaries while Li et al [22] proposed an adaptive image enhancement method using a dynamic filtering for speckle detection.

In this study, four commonly used image enhancement techniques which have different fundamental theories have been applied on pancreas ultrasound images. The techniques can be classified as nonlinear spatial domain filtering (median filter), frequency domain Gaussian low-pass filtering, histogram processing, and wavelet filtering.

2.2.1 Nonlinear Spatial Domain Filtering

In nonlinear spatial domain filtering, median filter is one of the most commonly used filters. Median filter is created by calculating the median value of the image by sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel with the middle pixel value. Median filtering, also known as rank filtering helps in speckle reduction and salt and pepper noise [23 - 25].Fig. 6 shows an example of calculating the median value.

140	**135**	**124**	**130**	**135**
128	**115**	**119**	**123**	**127**
130	**124**	**126**	**127**	**140**
138	**120**	**150**	**125**	**128**
125	**125**	**122**	**135**	**132**

Neighbourhood values: 115, 119, 123, 124, 126, 127, 120, 150, 125
Median Values : 124

Fig. 6: An example of calculating the median value for median filtering

2.2.2 Frequency Domain Gaussian Low-pass Filter

In frequency domain, the commonly used filter is the low-pass filter based on Gaussian function, since both the forward and the inverse Fourier transforms of a Gaussian are the real Gaussian functions.

The transfer function of a Gaussian low-pass filter (GLPF) is given by

$$H(u,v) = e^{-D^2(u,v)/2\sigma^2} \tag{4}$$

where σ is the standard deviation and *D(u,v)* is the distance from the origin of the Fourier transform [26].

2.2.3 Histogram Equalization

Histogram Equalization is a method which modifies the contrast and dynamic of the image by altering that image such that its intensity histogram has a desired shape. In most cases, peaks in the image histogram are widened, while the valleys are compressed [27, 28].

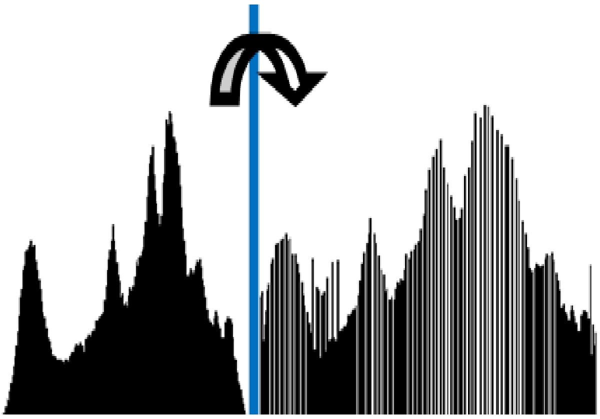

Fig. 7: Adjustment of histogram to distribute intensities

2.2.4 Wavelet Filtering

When digital images are to be viewed or processed at multiple resolutions, the discrete wavelet transform (DWT) is the mathematical tool of choice. The most popular technique in wavelet-based filtering is described by Donoho [19].

In wavelet-based filtering, the basic steps for removing the noise are [20]:

1) Decomposing the original image data into l-level of wavelet transform.
2) Performing thresholding of the resultant wavelet coefficients for noise suppression.
3) Performing wavelet reconstruction technique based on the original approximation coefficients.

Wavelet functions are different compared to other transformations such as Fourier transform, as they not only dissect signals into their component frequencies but also vary the scale at which the component frequencies are analyzed.

2.3 Image Segmentation

Ultrasound image segmentation is an important problem in medical image analysis and visualization. Because these images contain strong speckle noise and attenuation artifacts, it is difficult to automatically segment these images to detect interested objects in the correct position and orientation [29]. Many researches have been done on image segmentation and many new algorithms have been developed for a better US image segmentation. Mostly, the methods focus on thresholding techniques, edge or boundary-based methods, region based techniques, hybrid techniques, texture based or active contour methods [30].

For image segmentation process, level sets methods has been chosen. A new variational formulation of level set without re-initialization method has been proposed by Li et al. [31]. Generally they have proposed the following numerical integral:

$$\mathcal{P}(\emptyset) = \int_{\Omega} \frac{1}{2}(|\nabla\emptyset| - 1)^2 \, dxdy \tag{5}$$

Then, based on defined functional $\mathcal{P}(\emptyset)$, following variational formulation has develop:

$$\mathcal{E}(\emptyset) = \mu\mathcal{P}(\emptyset) + \mathcal{E}_m(\emptyset) \tag{6}$$

where;

$\mu > 0$ = parameter control

$\mathcal{E}_m(\emptyset)$ = energy to drive the motion of zero level curve

Basically, there are few advantages by using this new proposed method. This method gives a fast curve evolution and it can be simply implemented via simple finite difference. The level set function can also be initialized with general functions that are more effective and efficient to construct thus make it easier to practically use compared to commonly use signed distance function [31-34].

3 Results and Analysis

The results of the study were divided into few parts according to the steps applied consist of comparison of image enhancement techniques, comparison of image segmentation techniques and pancreas size measurement.

3.1 Comparison of Image Enhancement Techniques

Fig. 8 shows the image after being enhanced using different enhancement techniques where (a) is enhanced using median filter, (b) is enhanced using frequency domain Gaussian low-pass filter, (c) is enhanced using histogram equalization and (d) is enhanced using wavelet filter.

Table 3 shows the result of MSE and PSNR of the images. In Table 3, median filter gives 0.000095 of MSE and 64.2703dB of PSNR, Gaussian filter gives 0.0034 of MSE and 48.7998dB of PSNR, histogram equalization gives 0.0438 of MSE and 37.65dB of PSNR, while wavelet filter gives 0.0343 of MSE and 38.7146dB of PSNR. Based on the result, it shows that median filter gives the best result, where the MSE value is lowest and PSNR value is highest compared to other enhancement techniques.

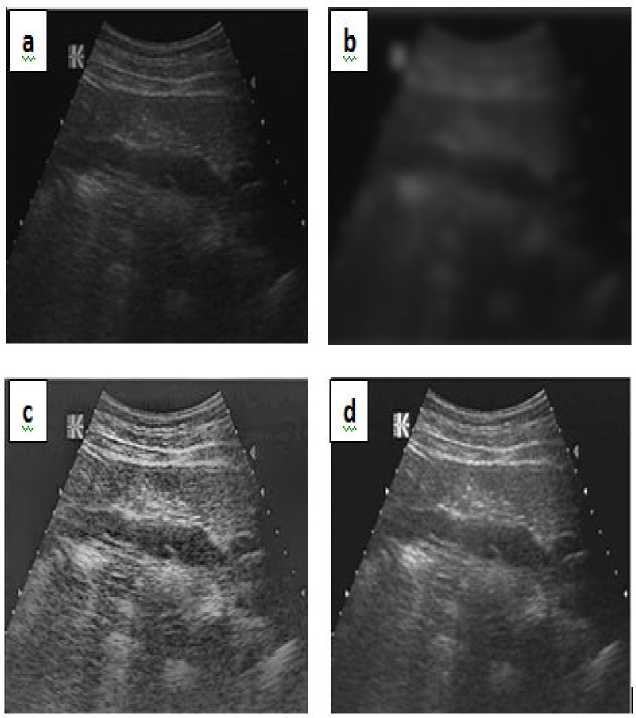

Fig.8: Image enhancement using (a) median filter, (b) frequency domain Gaussian low-pass filter, (c) histogram equalization, and (d) wavelet filter.

Table 3: MSE and PSNR of output images

Enhancement Techniques	MSE	PSNR (dB)
Nonlinear Spatial Domain Filtering (Median Filter)	0.000095	64.2703
Frequency Domain Gaussian Low-pass Filtering	0.0034	48.7998
Histogram Equalization	0.0438	37.6500
Wavelet Filtering	0.0343	38.7146

Therefore, for next image segmentation techniques, we median filter is choosed as pre-proseccing methods for enhancing the image. Fig. 9 is the output image of median filter.

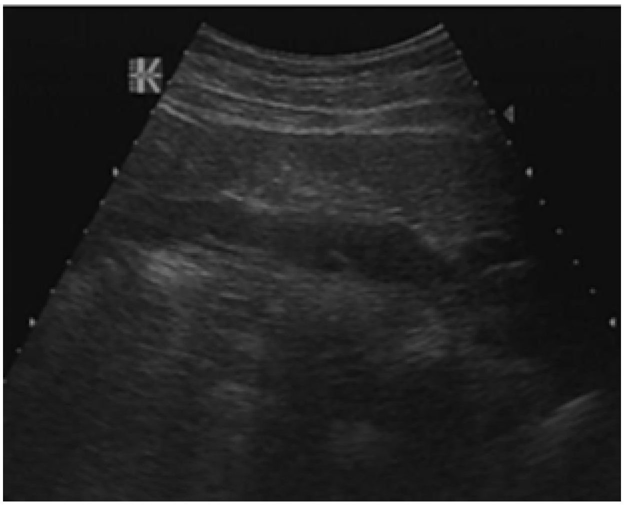

Fig. 9: Image after medial filter

3.2 Image Segmentation Techniques

After image enhancement step, the output image will undergo image segmentation methods. For this study, level sets segmentation was used. The output images for level sets segmentation were shown in Fig. 10 to Fig. 12.

Fig. 10 is the initial contour that the user needs to set. The contour is set inside the pancreas region and the level set segmentation method will segment the pancreas according to the iteration number set earlier. Fig. 11 shows the result of the segmentation after 60 iterations. Then, the output image is changed to binary image and the result can be seen as in Fig. 12.

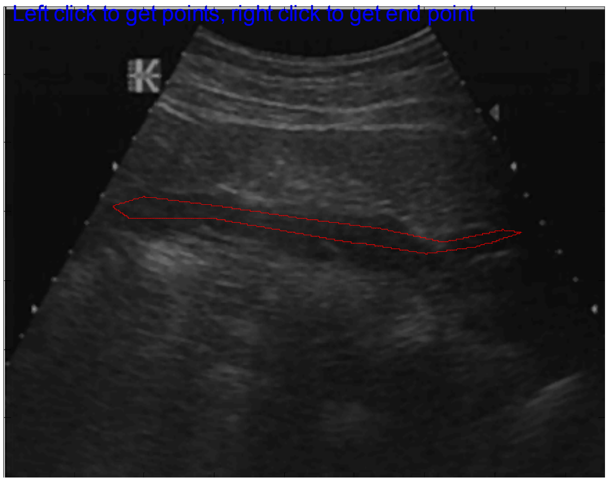

Fig. 10: Initial contour for level sets segmentation

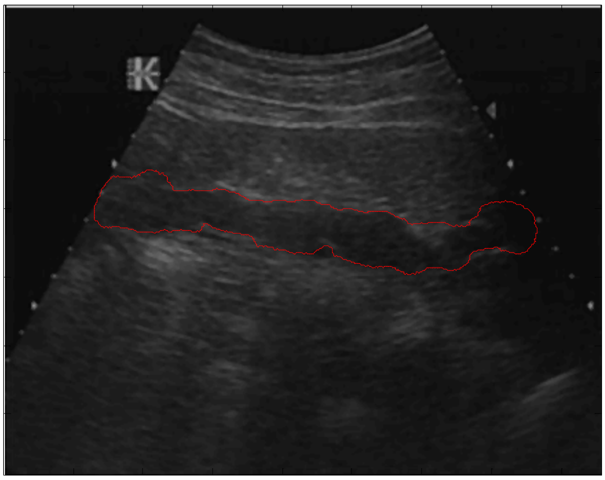

Fig. 11: Result after 60 iterations

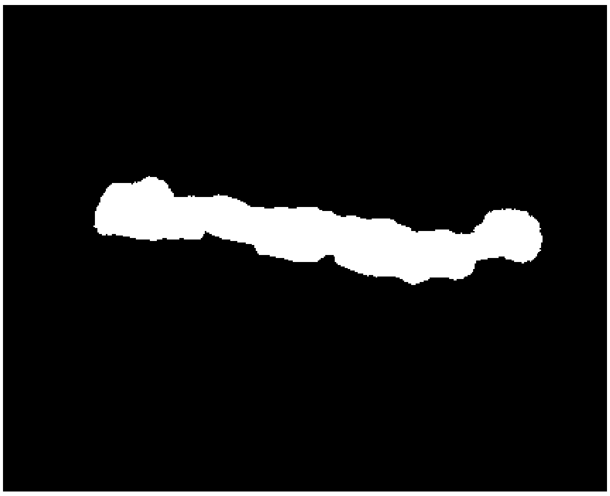

Fig. 12: Result after changed into binary image for measurement purpose.

3.3 Pancreas Size Measurement

After the segmentation process, the length (L) of the pancreas is measured using equation (3) as can be seen in Fig. 13.

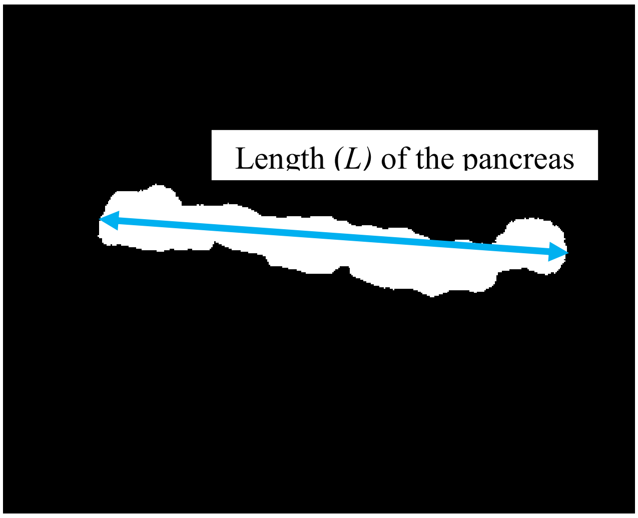

Fig. 13: Length measurement of the pancreas

For pancreas image in Fig. 13, the result is as follows:

The coordinate of Y max= [163, 380]
The coordinate of Y min = [155, 62]
The coordinate of X max = [164, 89]
The coordinate of X min = [126, 89]

length = 318 pixel

Length (L) = 8.4cm

The result is in pixel, thefore, it need to be converted into cm first. For this study, we performed for many other different ultrasound pancreas images for software verification. The average value that we measured is 8.5 ± 1.5 cm in length. However, there is problem of the ultrasound image for the pancreas as its' position is hidden behind the stomach and stick on the duodenum. Besides, in some cases, this proposed techniques are not really proficient in isolating the pancreas alone as there are low differences in the gray intensity. Hence, the improvement need to be taken into consideration not only regarding the enhancement techniques with better MSE and PSNR but also need to consider the improvement in contrasting the edge of the pancreas so that the level sets segmentation technique will work better.

4 Conclusion

Ultrasound imaging in screening of patients with pancreatic disease as well as diabetes mellitus can be widely used as it is potentially useful in diagnosis of the various pancreatic pathologies. Besides, it also can be used to see the progress of pancreatic necrosis lesions to its final resolution or to see the development of its complications.

For this study, we have developed a method for measuring the pancreas size consists of image enhancement as well as image segmentation. In optimizing the measuring technique, for image enhancement, we compare some commonly used enhancement techniques with different fundamental theories. Comparing the nonlinear spatial domain filtering (median filter), frequency domain Gaussian low-pass filtering, histogram equalization and wavelet filtering by calculating the MSE and PSNR values, we found out that median filter gives lowest value of MSE and highest value of PSNR. Next, we segmented the pancreas by using level sets methods for size measurement purpose.

Although there are some cases which cannot really isolate the pancreas alone from the surrounding tissues, the edge of the pancreas and the shape still can be clearly shown. Hence, this technique is still possible to aid the radiologist in identifying and measuring the length of the pancreas for detection of pancreatic diseases such as acute pancreatitis as well as diabetes mellitus. Hence, ultrasound can be proposed as a new approach towards detection of pancreatic diseases and diabetes mellitus by measuring the size of the pancreas. For more accurate result in segmenting the pancreas, it is suggested that other segmentation techniques should be taken into consideration.

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