Performance Evaluation of Liver Ultrasound Image using Image Processing Techniques

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***Abstract* – Liver disease is the 4th leading cause of death in the United States. According to new NHS (National Health Service) figures, deaths from liver disease in England have reached record levels, rising by 25% in less than a decade; heavy drinking, obesity and hepatitis are believed to be behind the rise. Ultrasound (US) Sonography is an easy-to-use and widely popular imaging modality because of its ability to visualize many human soft tissues/organs without any harmful effect. This paper will provide an overview of underlying concepts, along with algorithms for processing of liver ultrasound image. We have applied few steps of image processing, on the normal and diseased ultrasound liver images, performing different image enhancements and segmentation techniques, and assessing the performance of each techniques in terms of evaluation parameters. The applied enhancement techniques are Shock Filter and Spatial Filter. The processed images were then assessed, on the basis Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE), after that segmentation is performed. The applied segmentation techniques are Normal thresholding, Otsu thresholding and region based segmentation.**

Keywords – Filtering, Liver disease, Thresholding, Ultrasound.

I. INTRODUCTION

Latest statistics available from the Centers for Disease Control and Prevention and the American Liver Foundation, shows that Primary liver cancer is one of the few cancers on the rise in the United States.

Our Liver is the largest and a vital organ inside our body. It performs a wide variety of critical life sustaining functions, including changing food into energy, converting nutrients derived from food into essential blood components, producing proteins and enzymes , storing vitamins and minerals, making digestive liquid Bile (a yellowish-green liquid), metabolizing and detoxifying alcohol and poisons from the blood, helps in blood clotting and removes bacteria from the blood, maintaining hormone balances, help the human immune system to fight infection and many others. Liver disease is any condition that causes liver inflammation or tissue damage and affects liver function, when it become diseased or injured, the loss of these functions can cause significant damage to the body. Liver disease is also referred to as hepatic disease.

Liver pathologies can be classified into two main categories based on the degree of dispersion of disease [2], [3]:

a. *Diffused Liver Diseases:* Diffuse means it is widespread throughout our liver, in which at least one complete lobe of the liver is affected by the disease causing the deterioration of the cells of the liver. Fatty Liver, Fibrosis, Cirrhosis, Chronic Active Hepatitis (CAH) are come in this category.

b. *Focal Liver Diseases:* Focal Liver Lesions are localized liver diseases, where the pathology is concentrated in the small area in one or both of the liver lobes, while the rest of the liver volume or tissue remains normal. Solid Lesion (Tumors) and Fluid Lesion (Cyst) are the types of focal lesions. Here we deal with Focal lesions.

If detected early, many liver diseases are preventable or reversible and nearly all are less expensive to treat. We just have to focus our efforts and tackle this problem sooner rather than later. For early detection and qualitative diagnosis of liver diseases, Ultrasound (US) image is an easy-to-use and widely popular imaging modality because of its ability to visualize many human soft tissues/organs without any harmful effect [1].

Two common enhancement techniques have been applied for image analysis and interpretation including the spatial filtering and Shock filtering. These techniques were assessed by measuring the image quality by calculating the MSE and PSNR of the image [3], [4], [5]. After that, segmentation is performed by using two approaches Thresholding and region based segmentation. In thresholding approach, normal and Otsu thresholding are applied.

II. IMAGE ENHANCEMENT

The principal objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application. The enhancement process itself does not increase the inherent information content in the data; it simply emphasizes certain specified image characteristics [3], [4], [5].

Enhancement is purely application dependent and well proved with the simulation results of various image enhancement techniques using MATLAB. In this work, we evaluate the performance of two enhancement techniques on the basis of two parameters PSNR and MSE.

A. Shock Filter

Shock filter is used for deblurring signals and images by creates discontinuity at inflection points. Shock filters satisfy a maximum-minimum principle gives that the range of the filtered image remains within the range of the original image. The dilation process is used near a maximum and an erosion process around a minimum.

The decision about the influence zone of the pixel (whether maximum or a minimum) is made on the basis of the Laplacian. The pixel is considered to be in the influence zone of a maximum for negative Laplacian, and for positive Laplacian, it belongs to the influence zone of a minimum. Iterating this procedure produces a sharp shock at the borderline of two influence zones. Within each zone, a constant segment is created.

Let us consider a continuous image $f(x, y)$. Then a class of filtered images of $f(x, y)$ may be generated by evolving f under the process.

The Kramer and Bruckner definition can be expressed using the following PDE [6]:

$$u_t = \text{sign}\ (\text{delta}\ (u)).*\left|\text{gradient}\ (u)\right| \quad (1)$$

$$u_t = -\text{sign}\ (\Delta u)\left|\nabla u\right| \quad (2)$$

When the pixels are in the influence zone of a maximum (negative Laplacian) i.e. $\Delta u = u_{xx} + u_{yy}$ is negative. Then a dilation equation is

$$u_t = \left|\nabla u\right| \quad (3)$$

For positive Laplacian, pixels belong to the influence zone of a minimum, with $\Delta u < 0$, then (3) can be reduced to an erosion equation i.e.

$$u_t = -\left|\nabla u\right| \quad (4)$$

These two cases show that for increasing time, (2) increases the radius of the structuring element until it reaches a zero-crossing of Δu, Then a shock is produced due to meeting of the influence zones of a maximum and a minimum, which separates adjacent segments. Thus, the zero-crossings of the Laplacian serve as an edge detector [7], [8]. Basically the result is enhancement/sharpening of the input image.

B. Spatial Filter

Spatial filters are employed to remove noise from image data. Spatial filtering term is the filtering operations which performed directly on the pixels of an image. Spatial filters are used to produce smoothing effect, spatial mask are used for it [3] [9]. Spatial mask is nothing but a kind of finite impulse response filter (FIR filter), usually has small support 2x2, 3x3, 5x5, 7x7, this mask is convolved with the image.

The result is the sum of products of the mask coefficients with the corresponding pixels directly under the mask and we get the filtered image [14]. If the operation is linear, the filter is said to be a linear spatial filter.

$$g(x, y) = T[f(x, y)] \quad (5)$$

Where T operates on the neighborhood of pixels.

Consider an image f of size $M \times N$ with a filter mask of size $m \times n$, the expression for linear filtering is given as:

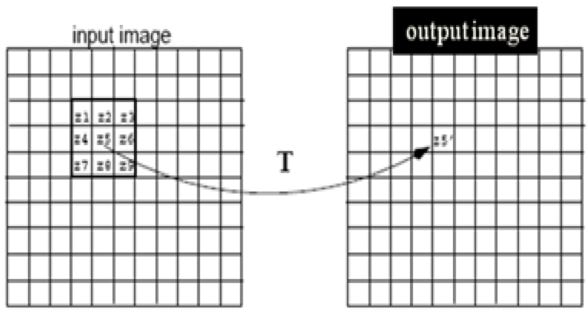

Fig. 1 : Area or mask processing Method

$$g(x, y) = \sum_{t=-a}^{a} \sum_{t=-b}^{b} w(s, t) f(x + s, y + t) \quad (6)$$

Here a and b are nonnegative integer. The Spatial filter method applied by using two type of filter, Low Pass Filter (LPF) and High Pass Filter (HPF).This applying to choose the best guesses for enhancement image. We get different filtered output, based on the type of spatial filter used.

The normal, benign, malignant Ultrasound images are used as test images to evaluate the performance of the above methods.

III. IMAGE SEGMENTATION

Segmentation subdivides an image into its constituent regions or objects. The level to which segmentation is carried depends on the problem being solved.

Segmentation algorithms are based on one of two basic properties of intensity values, which are discontinuity and similarity [5], [10]. The result of image segmentation is a set of segments extracted from the image and pixels belong to each region or segments are similar with respect to some characteristic, such as color, intensity or texture. Adjacent regions are significantly different with respect to the same characteristics. Some of the Segmentation techniques applied are given below:

A. Thresholding

Thresholding is one of the simplest techniques for Image Segmentation, which provides an easy and convenient way of segmentation based on the different intensities or colors in the foreground and background regions of an image. Thresholding is a non-linear operation which converts a gray-scale image into a binary image in the simplest implementation. Thresholding can be used as preprocessing to extract an interesting subset of image structures which will then be used for further image processing chain [10].

Several different methods exist for choosing a threshold; users can manually choose a threshold value, or can compute a value automatically by a thresholding algorithm, which is known as automatic thresholding.

B. OTSU Thresholding

The Otsu method is a popular non-parametric method in medical image segmentation, because of the ease of implementation and the relative complexity. Otsu's method is used to automatically perform histogram shape-based image thresholding.

Its basic objective is to classify the pixels of a given image into two classes or bi-modal histogram (e.g. foreground and background), then calculate the optimum threshold separating those two classes minimizes the intra-class variance (within class variance), defined as a weighted sum of variances of the two classes [11], [12].

It is based on the threshold for partitioning the pixels of an image into two classes C_1 and C_2 (e.g., objects and background) at grey level t, where $C_1 = \{1, 2, 3\ldots, t\}$ and $C_2 = \{t + 1, t + 2, \ldots. l\}$, and let q_1 and q_2 represent the estimate of class probabilities defined as follows:

$$q_1(t) = \sum_{i=1}^{t} P(i) \quad (7)$$

$$q_2(t) = \sum_{i=t+1}^{l} P(i) \quad (8)$$

The class means are given by:

$$\mu_1(t) = \sum_{i=1}^{t} \frac{iP(i)}{q_1(t)} \quad (9)$$

$$\mu_2(t) = \sum_{i=t+1}^{l} \frac{iP(i)}{q_2(t)} \quad (10)$$

Finally, the individual class variances are:

$$\sigma_1^2(t) = \sum_{i=1}^{t} [i - \mu_1^2(t)]^2 \frac{P(i)}{q_1(t)} \quad (11)$$

$$\sigma_2^2(t) = \sum_{i=t+1}^{l} [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)} \quad (12)$$

The weighted within-class variance is:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t) \quad (13)$$

For any given threshold, the total variance is the sum of the weighted within-class variances and the between class variance, we can express the total variance as:

$$\sigma_T^2(t) = \sigma_w^2(t) + \sigma_b^2(t) \quad (14)$$

Where, $\sigma_w^2(t)$ = within-class variance,

$\sigma_b^2(t)$ = between class variance, which is the sum of weighted squared distances between the class means and the grand mean. Then the total variance is given as:

$$\sigma_T^2(t) = \sigma_w^2(t) + q_1(t)[1 - q_1(t)][\mu_1(t) - \mu_2(t)]^2 \quad (15)$$

Since the total variance is constant and independent of t, the effect of changing the threshold is just moving the contributions of the two terms back and forth.

So, minimizing the within-class variance is the same as maximizing the between-class variance, thus we can compute the quantities in $\sigma_b^2(t)$ recursively as we run through the range of t values.

Finally, the above expression can safely be maximized and the solution is the value of t, which corresponds to desired threshold that maximizing $\sigma_b^2(t)$.

C. ROI Based Processing

Region is basically a group of connected pixels with similar properties. Region of interest (ROI) is a portion of an image that we want for further processing. ROI is defined by creating a binary mask. The Radiologists distinguish between normal and diseased liver by using some major parameters through visual interpretations [13], [5]. These parameters are Contrast, Homogeneity, Fineness (or Roughness), ratio of Echogenicity. By these visual criteria ROI is selected and image or a particular ROI is cropped using Image Tool. These cropped regions are assessed based on MSE and PSNR.

IV. ASSESSMENT PARAMETERS

The two parameters used for the performance evaluation of various enhancement methods are given below [3], [9].

a. PSNR - The peak signal-to-noise ratio (PSNR) is the ratio between the maximum possible power of a signal and the power of corrupting noise, measure the degree of contrast enhancement. Greater PSNR is better. PSNR given by (16) is

$$PSNR = 10 . \log_{10}\left(\frac{Max_I}{MSE}\right) \qquad (16)$$

Here, Max_I is the maximum possible pixel value of the image. When samples are represented using linear PCM with B bits per sample, Max_I is 2*B*−1.

b. MSE - The Mean Square error (MSE) represents the cumulative squared error between the compressed and the original image. The lower the value of MSE, lower the error. MSE is given by:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[x(i,j) - y(i,j)]^2 \qquad (17)$$

Where $x(i,j)$ is noise-free $m \times n$ grayscale image and $y(i,j)$ is noisy approximation of $x(i,j)$.

V. RESULT AND ANALYSIS

We have applied various enhancement and segmentation techniques for ultrasound liver image using MATLAB tool. These techniques are then compared in terms of PSNR and MSE. After enhancement we have done normal and OTSU thresholding. The images taken as input are shown in Fig. 2, Fig. 3 and Fig. 4.

Fig. 2 shows the normal liver image. Fig. 3 shows a benign liver image, i.e. liver having cyst in it. Fig. 4 shows a malignant liver image, in which liver is affected by Hepatocellular carcinoma (HCC), the most common type of liver cancer.

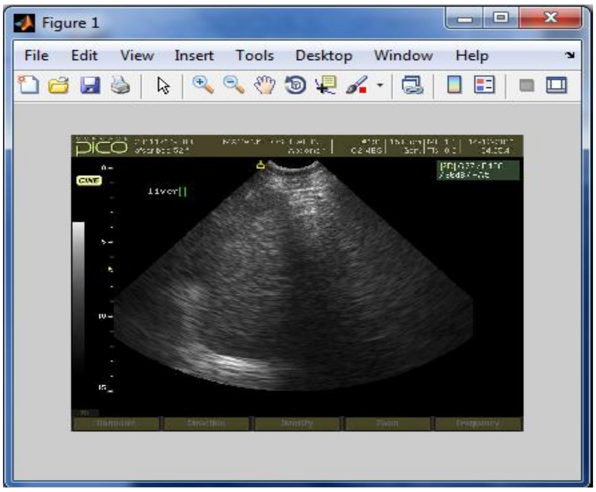

Fig. 2 : Normal Liver Image

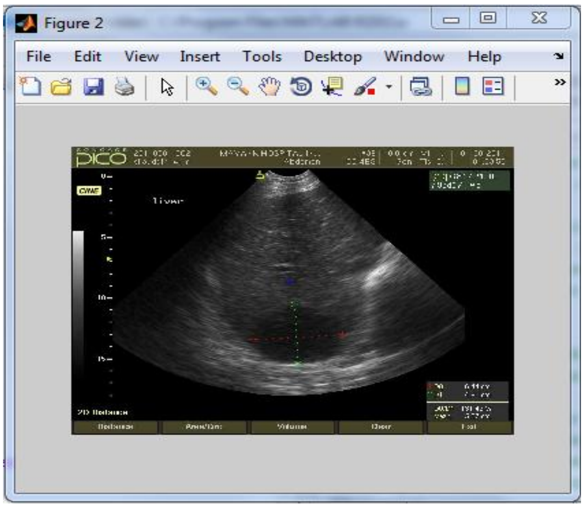

Fig. 3 : Benign Liver Image

Fig. 4 : Malignant Liver Image

The corresponding comparison table for different enhancement techniques in terms of MSE and PSNR is given below by Table I.

Table I. Performance of Various Enhancement Techniques for Normal, Benign and Malignant Liver image

Type of Image	Enhancement Techniques	Parameters	
		MSE	PSNR
Normal Liver Image	Original Image	197.68	25.21
	Shock Filter	175.28	25.73
	Spatial LP	174.07	25.76
	Spatial HP	162.36	26.06
Benign Liver Image	Original Image	197.96	25.20
	Shock Filter	176.47	25.70
	Spatial LP	173.31	25.78
	Spatial HP	164.09	26.01
Malignant Liver Image	Original Image	212.24	24.90
	Shock Filter	174.25	25.75
	Spatial LP	188.19	25.42
	Spatial HP	183.19	25.54

The output of OTSU thresholding for normal, Benign and malignant Liver images are given by Fig. 5, Fig. 6 and Fig. 7 respectively.

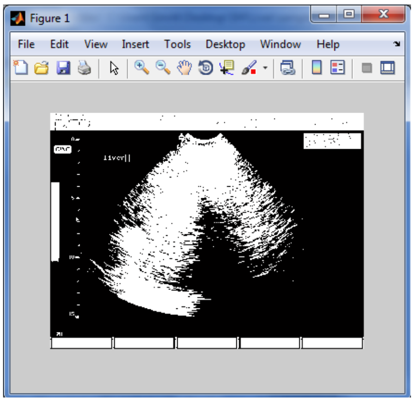

Fig. 5 : Segmented Normal Liver Image using OTSU thresholding

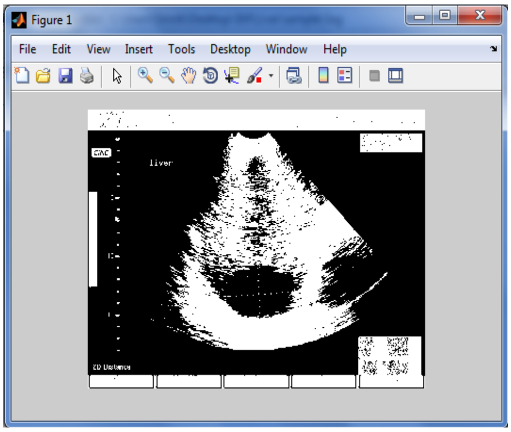

Fig. 6 : Segmented Benign Liver Image using OTSU thresholding

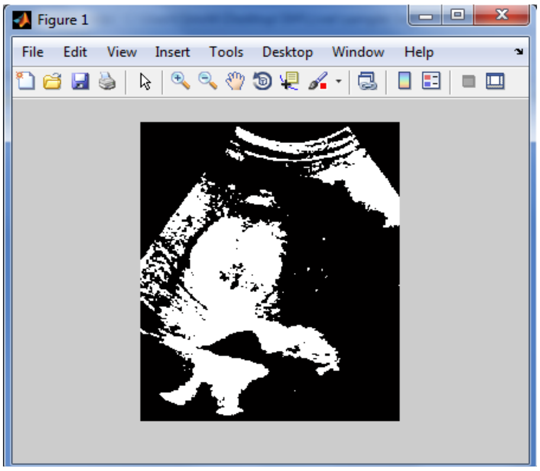

Fig. 7 : Segmented Malignant Liver Image using OTSU thresholding

In case of ROI based Segmentation we have taken ROI and then PSNR and MSE are calculated. Corresponding ROI images and assessment parameter values are given below:

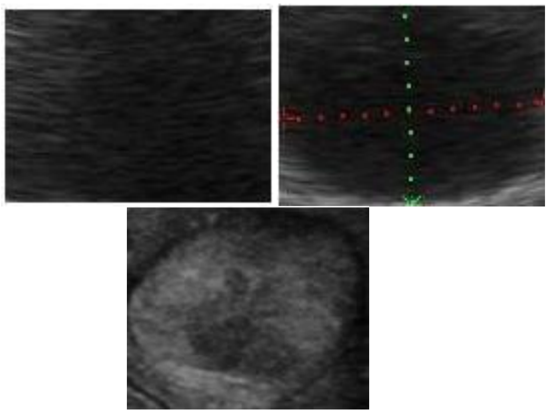

Fig. 8 : Region of Interest of Normal, Benign, Malignant Ultrasound Liver image

Table II. Performance Assessment for different ROI

ROI Type	Parameters	
	MSE	PSNR
Original	225.38	24.64
Benign	227.56	24.59
Malignant	252.36	24.14

VI. CONCLUSION

In this paper, two image enhancement techniques have been applied for the smoothing or filtering of noises in ultrasound images. The enhanced images are analyzed with the help of two assessment parameters MSE and PSNR. By observing the table it is clear that Spatial High Pass filter gives the minimum MSE and highest PSNR value than the shock filter. Then we have applied Thresholding based segmentation and ROI based segmentation. We have also calculated MSE and PSNR for different ROI images. This work is under extension and in near future we will concentrate on the feature extraction techniques for the ultrasound liver image and more number of ultrasound images will be analyzed.

VII. REFERENCES

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