International Journal of Electrical and Computer Engineering (IJECE)
Vol.2, No.6, December 2012, pp. 792~797
ISSN: 2088-8708

Comparative Analysis of Image Enhancement Techniques for Ultrasound Liver Image

Smriti Sahu*, Maheedhar Dubey*, Mohammad Imroze Khan**
*Department of Electronics & Telecommunication Engg, Chhatrapati Shivaji Institute of Technology, Durg, C.G. (India)
**Department of Electronics & Telecommunication Engineering, National Institute of Technology, Raipur, C.G. (India)

Article Info

Article history:

Received Aug 8, 2012
Revised Nov 10, 2012
Accepted Nov 25, 2012

Keyword:

Filtering
Histogram Equalization
Image enhancement
Liver disease
Ultrasound image

ABSTRACT

Liver cancer is the sixth most common malignant tumour in the world and the third most common cause of cancer-related deaths worldwide. To diagnose such liver diseases, In this paper comparison has been made for various image enhancement techniques that are applied to liver ultrasound image. Three types of liver ultrasound images used are normal, benign and malignant liver images. The techniques, which are compared on the basis of two evaluation parameters Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) including, Contrast Stretching, Shock Filter, Histogram Equalization, Contrast Limited Adaptive Histogram Equalization (CLAHE). Such a comparison would be helpful in determining the best suited method for clinical diagnosis. It also has been observed that the Shock filter gives the better performance than others for liver ultrasonic image analysis.

Corresponding Author:

Smriti Sahu,
Department of Electronics & Telecommunication Engineering,
Chhatrapati Shivaji Institute of Technology,
Durg, Chhattisgarh, India
Email: smritisahu13@gmail.com

1. INTRODUCTION

In the last few years, large parts of research have been focused on the processing of biomedical signals. Since it has been seen that biomedical signal processing is used during monitoring of patients and for diagnostic purpose, therefore automatically processing systems are frequently required in medical data analysis. New techniques can simplify and speed up the processing of large amount of data analysis

Since Liver cancer is the sixth most common malignant tumour in the world and the third most common cause of cancer-related deaths worldwide. It is estimated that liver diseases are among the top ten killer diseases in India, causing lakhs of deaths every year. Liver ultrasound image plays an important role in monitoring and diagnostic of the patients. Ultrasound techniques offer important information about health of patients and physicians are able to recognize different liver diseases [1]. Liver diseases are frequent reason of death over worldwide, therefore many researcher group have focused on the liver image analysis.

Here, in this work, image enhancement techniques are applied for early detection of liver disease [2-5]. Image enhancement is simple area among all the digital image processing techniques. The main purpose of image enhancement is to bring out details that are hidden in an image.

For the analysis purpose, various image enhancement techniques are used including Contrast Stretching, Shock Filter, Histogram Equalization, Contrast Limited Adaptive Histogram Equalization CLAHE. These techniques are applied on the three types of liver ultrasound images, which are normal, benign and malignant liver images [2]. The comparison has done among the techniques on the basis of two evaluation parameters Peak signal to noise ratio (PSNR) and Mean square error (MSE) [4],[11]. It also has been described which technique is best suited for liver image analysis and gives better performance than others.

2. RESEARCH METHOD

The principle objective of enhancement is to process an image so that the result is more suitable than the original image for analysis purpose. For early detection of liver diseases, we have applied image processing techniques. Here we concerned to Image Enhancement techniques and some of these are described below.

2.1. Contrast Stretching

Contrast stretching is a simple image enhancement technique that improves the contrast in an image by stretching the range of pixel intensity values, to extend a desired range of values. This method can only apply a linear scaling function to the image pixel values [6].

By contrast stretching a low-contrast image can be transformed into a high-contrast image by remapping or stretching the gray-level values in such a way that the histogram spans the full range [13]. In field of digital signal processing, it is referred to as dynamic range expansion. It can be expressed as shown in equation (1):

$$y = \begin{cases} \alpha x, & 0 \le x < a \\ \beta(x-a)+y_a, & a \le x < b \\ \gamma(x-b)+y_b, & b \le x < L \end{cases} \quad (1)$$

Where, x is an input image and y is the Stretched output and α, β and γ are the stretching constants, act as multiplier. Here, a and b are the lower and the higher range, y_a and y_b are given below by equation (2) and (3):

$$y_a = \alpha a; \quad (2)$$

$$y_b = \beta(b-a)+y_a \quad (3)$$

The purpose of contrast stretching in the various applications is to bring the image into a range which is more familiar or normal to senses, hence it is also called normalization [5].

2.2. Shock Filter

Shock filter is used for deblurring signals and images by creates shocks at inflection points. Shock filters apply either erosion or dilation process, in order to create a “shock” between two influence zones, one belonging to a maximum and the other to a minimum of the signal.

The concept is that 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 minimum for positive Laplacian. Shock filters satisfy a maximum-minimum principle gives that the range of the filtered image remains within the range of the original image [8]. The dilation and erosion process is iterated by using a Partial Differential Equation (PDE) according to a small time increment *dt*, which produces a sharp discontinuity called shock at the borderline between two influence zones and finally we get deblurred output.

The Kramer and Bruckner definition can be expressed using the following PDE [7] equation (4):

$$u_t = sign(delta(u).*\left|gradient(u)\right| \quad (4)$$

Let us consider a continuous image $f(x,y)$. Then a class of filtered images may be generated by evolving f under the process. The equation (4) can be written as equation (5):

$$u_t = -sign(\Delta u)\left|\Delta u\right| \quad (5)$$

Where subscripts denote partial derivatives, and $\nabla u = (u_x, u_y)^T$ is the gradient of u. Let us assume that some 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 given by equation (6).

$$u_t = \left|\nabla u\right| \quad (6)$$

For positive Laplacian, pixels belong to the influence zone of a minimum, with $\Delta u < 0$, then (2) can be reduced to an erosion equation given by equation (7).

$$u_t = -|\nabla u| \quad (7)$$

Thus, the zero-crossings of the Laplacian serve as an edge detector. Basically the result is enhancement/sharpening of the input image.

2.3. Histogram Equalization

A histogram is basically a visual representation of the uniform distribution of pixels. Histogram equalization (HE) is a popular technique for enhancing image contrast due to its simplicity and effectiveness [9], [13]. This method increases the global contrast of the image, and adjust image intensities to enhance contrast by spreading out the most frequent intensity values [4]. By this, the intensities are better distributed on the histogram. Thus the areas of lower local contrast gain a higher contrast [3], [10].

Consider a discrete grayscale image $X = \{X(i,j)\}$ composed of L discrete gray levels denoted as $\{X_{0,} X_{1,} X_2 ......X_{L-1}\}$. For a given image X, the probability density function $P(X_K)$ is defined as in equation (8):

$$P(X_k) = \frac{n_k}{n} \quad (8)$$

Where n_k is number of occurrence of gray level X, n is total number of pixels in the image. Let us also define the cumulative distribution function (cdf) corresponding to $P(X_K)$ as shown in equation (9):

$$C(x) = \sum_{j=0}^{k} P(X_j) \quad (9)$$

Where x is X_k for $k = 0,1,....L-1$ and $0 \le C(X_k) \le 1$.

Histogram equalization is a mapping scheme that maps the input image into the entire dynamic range $(X_{0,} X_{L-1})$ by using the cdf as a level transformation function. A transformation function $f(x)$ based on the cdf is defined as in equation (10):

$$f(x) = X_0 + (X_{L-1} - X_0)C(x) \quad (10)$$

This is the desired output image of Histogram Equalization.

2.4. Contrast Limited Adaptive Histogram Equalization (CLAHE)

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a generalization of Adaptive Histogram Equalization and used to prevent the problem of noise amplification. The CLAHE algorithm partitions the images into contextual regions and applies the histogram equalization to each one [4]. This evens out the distribution of used grey values and thus makes hidden features of the image more visible. The method has three parameters:

Block size: It is the size of the local region around a pixel for which the histogram is equalized. This size should be larger than the size of features to be preserved.

Histogram bins: It is the number of histogram bins used for histogram equalization process. It should be smaller than the number of pixels in a block. This value also limits the quantification of the output when processing 8 bit gray or 24 bit RGB images.

Max slope: It limits the contrast stretch in the intensity transfer function. Very large values will result in maximal local contrast.

The method takes in one additional parameter ‘cliplevel’ which varies between 0 and 1. The method computes the histogram for each and every pixel and then does a equalization operation on the window or block size.

3. PERFORMANCE MATRICES

The two parameters used for the performance evaluation of various enhancement methods are given below [4], [11].

PSNR - The peak signal-to-noise ratio, abbreviated as PSNR, is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR can be represented by equation (11).

$$PSNR = 10.\log_{10}\left(\frac{Max_I^2}{MSE}\right) \quad (11)$$

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 $2^B - 1$.

MSE - The Mean Square error abbreviated as MSE represents the cumulative squared error between the the original image and its noisy approximation. The lower the value of MSE, the lower the error. MSE is given below by equation (12):

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[x(i,j) - y(i,j)]^2 \quad (12)$$

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

4. RESULTS AND ANALYSIS

Experiments were performed to evaluate different commonly used enhancement techniques for different type of diseased liver ultrasound images, by the comparison we can find the best suited method for enhancement of Liver ultrasound image. The images taken as input are shown below. Figure 1 shows the normal liver image. Figure 2 shows a benign liver image, i.e. liver having cyst in it. Figure 3 shows a malignant liver image, affected by Hepatocellular carcinoma (HCC).

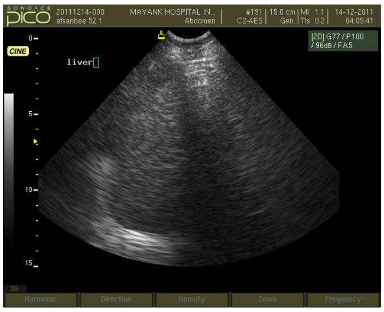

Figure 1. Normal Liver Image

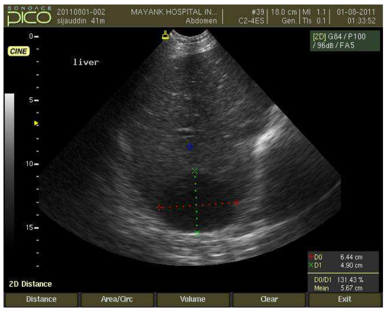

Figure 2. Benign Liver Image

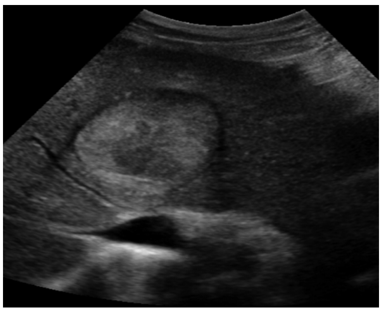

Figure 3. Malignant Liver Image

The comparison of various image enhancement techniques for gray scale images is carried out based on the two parameters that are Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE). These parameters are used as the objective measures for performance evaluation of applied enhancement methods. As per the evaluation, the result of normal, benign and malignent liver images are mentioned in following Table 1, Table 2 and Table 3.

Table 1. The Performance of Various Enhancement Techniques for Normal Liver Ultrasound Image

Type of Image	Enhancement Techniques	Parameters	
		MSE	PSNR
Normal Liver Image	Original Image	197.68	25.21
	Contrast Stretching	174.69	25.74
	Shock Filter	175.28	25.73
	Histogram Equalization	177.04	25.68
	CLAHE	180.95	25.59

Table 2. The Performance of Various Enhancement Techniques for Benign Liver Ultrasound Image

Type of Image	Enhancement Techniques	Parameters	
		MSE	PSNR
Benign Liver Image	Original Image	197.96	25.20
	Histogram Equalization	176.74	25.69
	Shock Filter	176.47	25.70
	Contrast Stretching	175.54	25.72
	CLAHE	182.65	25.55

Table 3. The Performance of Various Enhancement Techniques for Malignant Liver Ultrasound Image

Type of Image	Enhancement Techniques	Parameters	
		MSE	PSNR
Malignant Liver Image	Original Image	212.24	24.90
	Contrast Stretching	199.41	25.71
	Shock Filter	174.25	25.75
	Histogram Equalization	183.28	25.53
	CLAHE	187.01	25.45

5. CONCLUSION

In this paper, various image enhancement techniques have been applied for the analysis of ultrasound liver image and comparison has been done, which is helpful in determining best suited method for clinical diagnosis. By the above comparison table it is clear that Shock filter gives the minimum MSE and highest PSNR value, therefore it is the best suited method and has given better performance than others. Accordingly, it gives better visual perception to sonographer for the liver disease diagnostic purpose. In future, we will apply other approachs of Biomedical image processing for better performance.

REFERENCES

[1] Katsutoshi Sugimoto, *et al.*, "Computer-Aided Diagnosis for Contrast-Enhanced Ultrasound in the Liver", World Journal of Radiology, Vol. 2, Issue 6, pp. 215-223, ISSN 1949-8470, 28 June 2010.

[2] Hyun-Jung Jang, *et al.*, "Contrast-Enhanced Ultrasound in the Detection and Characterization of Liver Tumors," *International Cancer Imaging Society, 2009*, DOI: 10.1102/1470-7330.2009.0015.

[3] Vibhakar Shrimali, *et al.*, "Comparing the Performance of Ultrasonic Liver Image Enhancement Techniques: A Preference Study," *IETE Journal of Research*, Vol. 56, Issue 1, Jan-Feb 2010.

[4] Wan Mahani Hafizah, *et al.*, "Comparative Evaluation of Ultrasound Kidney Image Enhancement Techniques," *International Journal of Computer Applications* (0975 – 8887), Vol. 21– No. 7, May 2011.

[5] H. K. Sawant, *et al.*, "A Comprehensive Review of Image Enhancement Techniques," *International Journal of Computer Technology and Electronics Engineering (IJCTEE)*, Vol. 1, Issue 2, pp. 39-44, ISSN 2249-6343.

[6] Mr. Salem Saleh Al-amri, *et al.*, "Linear and Non-linear Contrast Enhancement Image," *IJCSNS International Journal of Computer Science and Network Security*, Vol. 10, No. 2, February 2010.

[7] Joachim Weickert, "Coherence-Enhancing Shock Filters," *Pattern Recognition, Springer*- 2003.

[8] Cosmin Ludusan, *et al.*, "Image Enhancement Using a New Shock Filter Formalism", *Acta Technica Napocensis, Electronics and Telecommunications*, Vol. 50, No. 3, 2009.

[9] Yeong-Taeg Kim, "Contrast Enhancement Using Brightness Preserving Bi-Histogram Equalization," IEEE Transactions on Consumer Electronics, Vol. 43, No. 1, February 1997.

[10] Hojat Yeganeh, *et al.*, "A Novel Approach for Contrast Enhancement Based on Histogram Equalization," *Proceedings of the International Conference on Computer and Communication Engineering 2008*, May 13-15, 2008 Kuala Lumpur, Malaysia, 978-1-4244-1692-9/08 ©2008 IEEE.

[11] Md. Robiul Hoque *et al.*, "A New Approach in Spatial Filtering to Reduce Speckle Noise", *International Journal of Soft Computing and Engineering (IJSCE)*, ISSN: 2231-2307, Vol. 1, Issue-3, July 2011.

[12] Rakhi Chanan *et al.*, "Spatial Domain based Image Enhancement Techniques for Scanned Electron Microscope (SEM) images" *IJCSI International Journal of Computer Science Issues*, Vol. 8, Issue 4, No. 2, July 2011.
[13] Rafeal C. Gonzalez, *et al.*, "Digital Image Processing," Prentice Hall, 2nd Edition, 2006, ISBN 0-201-18075-8.

BIOGRAPHIES OF AUTHORS

Smriti Sahu received her B.E.degree in Electronics and Communication, from Chhattisgarh Swami Vivekanand Technical University, Bhilai, Chhattisgarh, India in 2009 and pursuing M.E. in Electronics and Communication from Chhatrapati Shivaji Institute of Technology, Durg, Chhattisgarh, India. Presently she is working as an Asst. Prof. in the Department of Electronics and Communication Engineering at Shri Shankaracharya College of Engineering and Technology, Bhilai. Her research interest includes Digital Image Processing, Biomedical Image Processing and Communication.

Maheedhar Dubey completed Master of Engineering in VLSI Design, currently working as an Assistant Professor in Electronics & Telecommunication Department in Chhatrapati Shivaji Institute of Technology, Durg, Chhattisgarh, India. He has 4 years of teaching experience. He has published / communicated 6 publications in National/ International Journals and conferences. He is the member of five professional societies like IEI, ISTE, IETE, ISCA, and IEEE. He has published four books & also one book published by an International Publisher of Germany. His research interest includes VLSI, VHDL and Image processing.

Mohammad Imroze Khan received B.E. degree in Electronics & Telecommunication Engineering from Pt. Ravishankar Shukla University, Raipur, Chhattisgarh in 2005 and M. Tech. in Electronics Instrumentation from College of Engineering, Pune, Maharashtra in 2008. He has 3.5 years of teaching and 2 years of Industrial experience. Presently, he is working as a lecturer in Department of Electronics & Telecommunication, National Institute of Technology, Raipur. He has published / communicated 20 publications in National/ International Journals and conferences. His research areas of interest are Image Processing, Embedded System, Cryptography and Network Security.