Comparative Study on Noise Reduction in Ultrasound Liver Images

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ABSTRACT

The gray scale digital image is an aggression of intensity values, represented in the form of two-dimensional array. But the digital images get corrupted by noise during acquisition and transmission. Noise is termed as any irrelevant data that obscures the authenticity of original data. Several noise removal algorithms are applied to ultrasound images in order to remove/reduce the noise level and improve the visual quality for better diagnoses. In the proposed method three algorithms named Median Filtering, Convolution and Wavelet Transform have been used on different ultrasound images and we have calculated the Relative Signal to Noise Ratio have been calculated for the measurement of image quality performance.

General Terms

Digital Image Processing

Keywords

Ultrasound Images, SNR, Median, Convolution, Wavelet.

1. INTRODUCTION

Medical images are normally affected by noise due to various sources of interferences and other phenomena that affect the process of measurement in an imaging and acquisition system. Normally, the digital images get corrupted by noise during acquisition and/or transmission, due to the influencing parameters of these processes such as faulty sensors, atmospheric turbulence [1], [2]. As a result,

the image quality is degraded and the effectiveness and accuracy of its subsequent processing courses such as edge detect, image segmentation, feature extraction and pattern recognition are negatively affected. So it is necessary to remove the noise from the image using an image filter. But the effective removal of the noise is often accomplished at the expense of blurred or even lost features [11]. Noise is termed as any irrelevant data that obscures the authenticity of original data. In many applications it is very important to remove noise in the images before some subsequent processing such as edge detection, object recognition and image segmentation. Any noise-prone image has to necessarily undergo restoration process in order to make it suitable for subsequent higher order processing. Image restoration is an objective preprocessing technique that aims to estimate the original intensities of the corrupted pixels based on the mathematical model of noise, as noises are classified as impulse noise, Gaussian noise, Poisson noise, thermal noise, speckle noise, exponential noise, uniform noise etc., based on their pattern of distribution and characteristics [4]. Salt and pepper noise is a form of noise typically seen on ultrasound images. It represents itself as randomly occurring white and black pixels. Speckle is a characteristic phenomenon in laser, synthetic aperture radar images, or ultrasound images. speckle is caused by interference between coherent waves that, backscattered by natural surfaces, arrive out of phase at the sensor[5,6]. Speckle can be described as random multiplicative noise. It hampers the perception and extraction of fine details in the image. This technique can be applied to ultrasound images in order to reduce the noise level and improve the visual quality for better diagnoses. In the present work, noise removal from ultrasound images are based on Median filters, Convolution and Wavelet Transform. The proposed algorithms are implemented using MATLAB(R2007) 7.4.0 and experimental results show that the algorithm for the enhancement of gray level image gives effectiveness and no loss of information.

2. ALGORITHMS USED

In image processing, several algorithms belong to a category called windowing operators. Windowing operators use a window, or neighborhood of pixels, to calculate their output. For example, windowing operator may perform an operation like finding the average of all pixels in the neighborhood of a pixel. The pixel around which the window is found is called the origin. Median filter, convolution filter are based on the usage of image processing algorithms using these pixel windows to calculate their output. Although a pixel window may be of any size and shape, a square 3x3 size was chosen for this application because it is large enough to work properly and small enough to implement efficiently on hardware.

2.1 Median Filter

Median filtering has proved an effective way to satisfy the dual requirements of removing impulse noise while preserving rapid signal changes[12,13]. Median filters have been used extensively in image processing for removing speckle noise and salt and pepper noise from images[1,3]. The rank order filter is a particularly common algorithm in image processing systems. It is a nonlinear filter, so while it is easy to develop, it is difficult to understand its properties. It offers several useful effects, such as smoothing and noise removal. The median filter, is especially useful in noise removal [4]. A classic general purpose Median filter is based on a 'Bubble Sort' approach [14], which uses a bubble sorter over the entire window elements to find the median value. .Median filters operate by replacing a given sample in a signal by the median of the signal values in a window around the sample. Given an input vector x(n) then y(n) is the output of a median filter of length l where l defines the number of samples over which median filtering takes place. Where l is odd, the median filter can be defined as:

$$y(n) = \text{median } \{x(n - k : n + k),\ k = (l - 1)/2\}$$

In effect, the original sample is replaced with the middle value obtained from a sorted list of the samples in the neighborhood of the original sample. In cases where l is even, the median is obtained as the mean of the two values in the middle of in the sorted list. As opposed to moving average filters, median filters are effective in removing impulse noise because they do not depend on values which are outliers from the typical values in the region around the original sample. For every pixel in an image, the window of neighboring pixels is found. Then the pixel values are sorted in ascending, or rank, order. Next, the pixel in the output image corresponding to the origin pixel in the input image is replaced with the value specified by the filter order.

2.2 Convolution

Convolution is another commonly used algorithm in DSP systems. It is from a class of algorithms called spatial filters. Spatial filters use a wide variety of masks, also known as kernels, to calculate different results, depending on the function desired. For example, certain masks yield smoothing, while others yield low pass filtering or edge detection. The convolution algorithm can be calculated in the following manner. For each input pixel window, the values in that window are multiplied by the convolution mask. Next, those results are added together and divided by the number of pixels in the window. This value is the output for the origin pixel of the output image for that position. Mathematically, this is represented using the following equation :

$$y(n1,n2) = \Sigma_{k1}\ \Sigma_{k2}\ A(k_1,k_2)\ k(n_1\text{-}k_1,\ n_2\text{-}k_2)$$

Input pixel window is always the same size as the convolution mask. The output pixel is rounded to the nearest integer. This convolution mask in this paper is often used as a noise – cleaning filter [5,6]. The results for this algorithm carried over an entire input image will result in an output image with reduced salt-and-pepper noise. An important aspect of the convolution algorithm is that it supports a virtually infinite variety of masks, each with its own feature. This flexibility allows for many powerful uses. For convolution the equation is ,

$$h(t) = \int f(\tau)\ g(t - \tau)\, d\tau$$

repeat for every value of t from [$-\infty$ to $+\infty$]. But for discrete convolution, integration is replaced by a summation and be defined as

$$h(t) = \Sigma_t\ f(\tau)\ g(t - \tau)$$

2.3 Wavelet Transform

Wavelets are developed in applied mathematics for the analysis of multiscale image structures [7]. Wavelet functions are distinguished from other transformations such as Fourier transform because they not only dissect signals into their component frequencies but also vary the scale at which the component frequencies are analyzed. As a result, Wavelets are exceptionally suited for applications such as data compression, noise reduction, and singularity detection in signals. Wavelet transform is an evolving technology which offers far higher degrees of data compression compared to standard transforms such as DCT etc. From the structural point of view, wavelet denoising involves three stages: (1) compute the DWT(discrete wavelet transform); (2) Threshold details wavelet coefficients; (3) Compute the IDWT (inverse discrete wavelet transform) to obtain the denoised estimate. The key idea of wavelet shrinkage is that the wavelet representation can separate the signal from the noise. For wavelet transform, the algorithm is structured as in an input image set the number of decompositions and color map and set matrices for approximation, horizontal, vertical, and diagonal coefficients. After inversing again all the above coefficients are set considering the approximation coefficient as the start image value in each step. By decomposing the image sub matrix, the final image is obtained.

3. RESULTS AND DISCUSSIONS

Three liver ultrasound images are considered and the algorithms are applied on those images separately [8,9]. Three algorithms were implemented using MATLAB (R2007)7.4.0 tool [10] and applied on these three images By eye observation it is found that wavelet transform has the best noise removal capacity which is also supported by the experimental results.

Table 1 shows the amount of noise that have been removed in the output images after applying the algorithms separately. It is found from the three sets of data, Wavelet Transform has the highest capacity to remove the noise. However, the performance of convolution filtering is in between the Wavelet Transform and Median Fltering.

Table 2 shows the relative performance of the three algorithms by calculating signal to noise ratio of the output images. Here, the performance of Median Filtering is taken as the reference and the performance of the other two algorithms have been calculated with respect to the performance of Median Filtering.

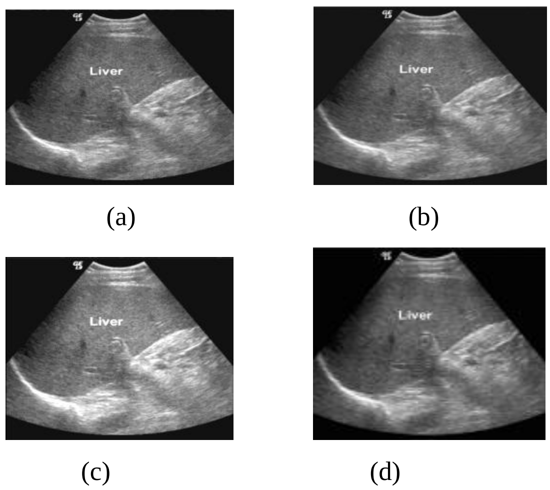
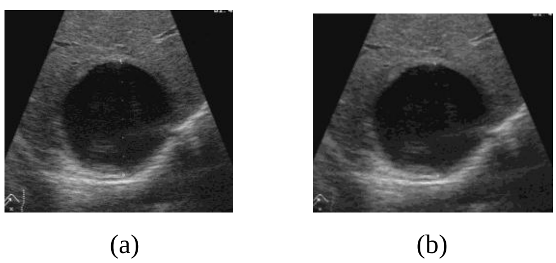
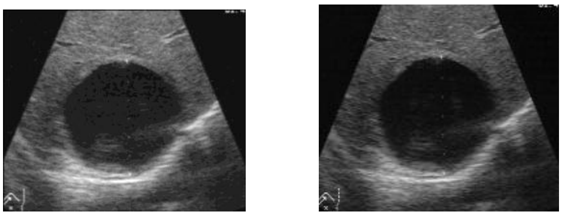


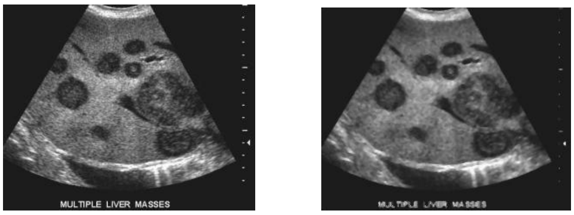
Fig 1: (a) Original Image, (b) after Median Filter, (c)after Convolution, (d)after Wavelet Transform



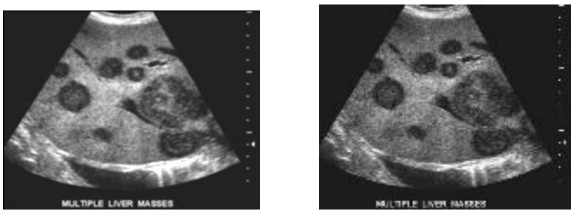


(c) (d)

Fig 2: (a) Original Image, (b)after Median Filtering, (c)after Convolution, (d)after Wavelet Transform



(a) (b)



(c) (d)

Fig 3: (a) Original Image, (b)after Median Filtering, (c)after Convolution, (d)after Wavelet Transform.

TABLE 1. NOISE CALCULATION BY THREE ALGORITHMS

Fig Number	Noise removed by Median Filter (unit)	Noise removed by Convolution Filter (unit)	Noise removed by Wavelet (unit)
Image 1	1.3027e+003	1.8187e+004	1.0928e+006
Image 2	1.4370e+003	6.3381e+003	1.4697e+006
Image 3	1.1288e+003	4.6170e+003	8.5026e+005

TABLE 2. RELATIVE PERFORMANCES OF THREE ALGORITHMS

Fig Number	SNR of Median Filter(taking as reference)	Relative SNR of Convolution Filter	Relative SNR of Wavelet Transform
Image 1	1	13.961004	838.8731
Image 2	1	4.4106472	1022.7557
Image 3	1	4.0901843	753.24238

TABLE 3. RMSE AND PSNR CALCULATION FOR IMAGE1

Filters	Root Mean Square Error	Peak Signal to Noise Ratio
Median	0.0117	199.7326
Convolution	0.0924	158.4539
Wavelet	69.9832	25.8602

TABLE 4. RMSE AND PSNR CALCULATION FOR IMAGE2

Filters	Root Mean Square Error	Peak Signal to Noise Ratio
Median	0.0261	183.7337
Convolution	0.0765	162.2260
Wavelet	66.1512	26.9864

TABLE 5. RMSE AND PSNR CALCULATION FOR IMAGE3

Filters	Root Mean Square Error	Peak Signal to Noise Ratio
Median	0.0427	173.9044
Convolution	0.0983	157.2294
Wavelet	71.8713	25.3277

4. CONCLUSION

Three imaging algorithms have been implemented using MATLAB (R2007) 7.4.0 tool. They have been operated on three ultrasound liver images in order to remove noises from the images. It is found that Wavelet Transform eliminates the highest amount of noise from all the three images. Therefore, we conclude wavelet transform algorithms is the best algorithm among the three algorithms chosen, in order to remove salt and pepper noise from bio-medical ultrasound images.

5. ACKNOWLEDGEMENT

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