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Performance Analysis of Image Enhancement Techniques for kidney Image

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ABSTRACT: Ultrasound imaging is one of the most preferred medical imaging which is the important bases for a diagnosis of disease. The edges and borders on image are not clear as expect due to interference. Speckle occurs especially in images of the liver and kidney whose underlying structures are too small to be resolved by large wavelength ultrasound. The main purpose of image enhancement is to bring out detail that is hidden in an image or to increase contrast in a low contrast image. In this paper, performance analysis for ultrasound image enhancement techniques like Wiener filtering, Wavelet filtering, Wavelet filtering and Gaussian filtering methods are done. The performance is evaluated based on Mean Square Error (MSE) and Peak Signal to noise ratio (PSNR).

KEYWORDS: Ultrasound kidney image, Wiener filter, Median filter, Wavelet filter, Gaussian filter, MSE, PSNR.

I.INTRODUCTION

Medical images that include computer tomography (CT), Magnetic resonance imaging (MRI), X ray and ultrasound image (US) are the important bases of disease diagnostic. Safely, portability and low cost aspects of ultrasound imaging have made it a significantly successful diagnostic imaging. Therefore, the ultrasound images are widely used in diagnostic imaging of heart diagnostic, anatomical structures, blood flow measurement and tissue characterization etc.
Medical images are often affected by speckle noise which is undesirable. Since it degrades the image quality, the diagnosis of medical image becomes difficult. Low image quality is an obstacle for effective analysis, recognition, segmentation, feature extraction and quantitative measurements. Therefore it is necessary to improve contrast and suppress such noises while retaining as much as possible the important image features for more accurate diagnosis. Image enhancement is an important tool for improving the visual appearance of the ultrasound image.

Ultrasound image processing generally has two ways for different propose. One way is to detect and enhance contrast of the edges and organ borders, and leave the speckle region unchanged. The other way is to reduce the speckle to smooth the speckle regions adaptively and preserve the edge and tissue structure.

Several methods are proposed by various researchers to enhance the ultrasound image. Most filters are traditional techniques in spatial domain and can be categorized as linear and nonlinear filters. For the analysis purpose, various image enhancement techniques are applied on the kidney image including median filter, wiener filter, Gaussian filter and wavelet filter. The enhancement is evaluated based on the parameters like Mean square error (MSE), Peak signal to noise ratio (PSNR) etc.

In this paper, section II describes the related work done by various researchers and section III describes different ultrasound image enhancement methods. In section IV, the performance evaluation parameters are discussed and section V presents the results and analysis of various methods.

II.RELATED WORK

A number of techniques have been proposed for ultrasound image enhancement under spatial domain and frequency domain. This section highlights the work done by various researchers.

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Xin-Yu Zhang, Tian-Fu Wang [1] proposed entropy based local histogram equalization technique. Local histogram equalization (LHE) has been widely used in image enhancement. In medical ultrasound image the region of interest usually surrounds by large area of dark background, which contains little information but consume lots of computational resource. Direct application of LHE will not only be time-consuming but also affect the global visibility due to background distortion. LHE algorithm is applied on the center pixel of this sub-block. The method can accelerate the speed of processing and reduce the background distortion considerably.

Xiaoying Li, Dong C.Liu [4] uses dynamic filtering method for ultra image enhancement. Gajanand Gupta[9] compared improved median filter technique with median and mean filter techniques. One of the most commonly used nonlinear spatial domain filter is median filter.

Wen chien yen, Shen-chun tai[5] proposed ultra sound enhancement technique using dual tree wavelet method. When digital images are to be viewed or processed at multiple resolutions, the discrete wavelet transform (DWT) is the mathematical tool of choice.

III.METHODOLOGY

Median filtering

Median filter is a useful nonlinear digital image filtering. The median filter considers each pixel in the image in turn and looks at its nearby neighbors to decide whether or not it is representative of its surroundings. The median is calculated by sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. Median filtering is comparatively better that mean filter since it preserves some useful details in an image. It helps in reducing mainly speckle and salt and pepper noise. Median filtering is also called rank filtering. The major problem with the median filter is its computational cost and it introduces a significant amount of signal distortion due to which fine details are either distorted or lost completely.

123	125	126	130	140
122	124	126	127	135
118	120	150	125	134
119	115	119	123	133
111	116	110	120	130

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

Wavelet filtering

Wavelets are developed in applied mathematics for the analysis of multiscale image structures. 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. The ability to vary the scale of the function as it addresses different frequencies also makes wavelets better suited to signals with spikes or discontinuities than traditional transformations such as the Fourier transforms. The application of wavelets to medical image enhancement has been extensively studied and starts recently to be applied.

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When digital images are to be viewed or processed at multiple resolutions, the discrete wavelet transform (DWT) is the mathematical tool of choice. DWT provides an appropriate basis for separating the noise from an image. As the wavelet transform is good at energy compaction, the small coefficients more likely represent noise, and large coefficients represent important image features. The coefficients representing features tend to persist across the scales and form spatially connected clusters within each sub-band. These properties make DWT attractive for denoising. In wavelet-based filtering, the basic steps for removing the noise are:
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.

Wiener filter

Wiener filter is basically a restoring method, which performs an optimal tradeoff between inverse filtering and noise smoothing. In terms of mean square error, the Wiener filter is optimum. It reduces the total mean square error of inverse filtering and noises smoothing process. It also is a linear estimation of the original image.

Wiener filtering is one of the better techniques to reduce the speckle. It minimizes the mean square error. This filter is worked based on the computation of local image variance.

The approximate image or estimate of f in the frequency domain which satisfies the minimum error function is given by

$$\hat{F}(u,v)=\left[\frac{1}{H(u,v)}\frac{|H(u,v)|^2}{|H(u,v)|^2+K}\right]G(u,v) \quad \textbf{(1)}$$

The wiener filter tries to build an optimal estimate of the original image by enforcing a minimum mean square error between restored and original image. So the results obtained in the wiener filtering are closer to the original image.

Gaussian Low-pass filter

Gaussian filter is a class of lowpass filter based on the Gaussian probability distribution function used to blur images and remove noise and preserve the details. Gaussian Low-pass filtering has been used in previous researches for removing the speckle noise in ultrasound images. Gaussian filter has similar function as median filter but it uses different kernel, which has the bell-shaped distribution. Gaussian filter modifies the input by convolution with a Gaussian function. The transfer function of Gaussian low pass filter is given by,

$$H(u,v)=e^{-D^2(u,v)/2D_0{}^2} \quad \textbf{(2)}$$

Where, D(u,v) Distance from point (u,v) to the center of the frequency rectangle and D_0 is the cutoff frequency

$$D(u,v) = [(u-M/2)^2 + (v-N/2)^2]^{1/2} \quad \textbf{(3)}$$

Gaussian filter is used to remove noise and also preserve the edges.

IV.PERFORMANCE EVALUATION

During a kidney screening using ultrasound, medical doctors usually measure the kidney length and width. In order to have a more accurate measurement, clear edges of the kidney image is required. Therefore, this experiment will visually compare the output images of different enhancement techniques according to the medical doctors' preference. The assessment between the techniques are based on,

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1. Observer sensitivity: Comparing the output images visually.
2. Image quality measurement: Measuring the output images quality by the traditional distortion measurements such as MSE and PSNR.
3. Image segmentation testing: Applying one segmentation methods to the output images.

Besides, the quality of the images will also be measured by the traditional distortion measurements such as MSE and PSNR between the original images and the output images. The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality.

The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE indicates the lower the error.
To compute the PSNR, the block first calculates the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \quad (4)$$

Where $I_2(m,n)$ is the original image,
$I_1(m,n)$ is the output image, and
M, N is the size of the image.

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. The PSNR block computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed image. The higher PSNR indicates the better the quality of the compressed or reconstructed image.
Then the block computes the PSNR using the following equation:

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad (5)$$

$$R = 2^n - 1 \quad (6)$$

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

V.RESULT AND ANALYSIS

The ultra sound image enhancement techniques are implemented in MATLAB. Kidney image is taken as a sample image and the corresponding output images are obtained. The results are compared based on performance evaluation parameters and are tabulated.

Table 1: MSE and PSNR of different filtering techniques for ultrasound kidney image

Filtering Technique	MSE	PSNR (dB)
Median filter	18.58	31.61
Wiener filter	24.91	37.91
Wavelet filter	29.87	42.89
Gaussian filter	26.89	38.4

The performance of different filters is compared based on the parameters like MSE and PSNR. The table 1 shows that the median filter have the lowest MSE (18.58) among the four filters which are analyzed and the wavelet filter has the highest PSNR (42.89) value. The filter which is having higher PSNR is preferable.

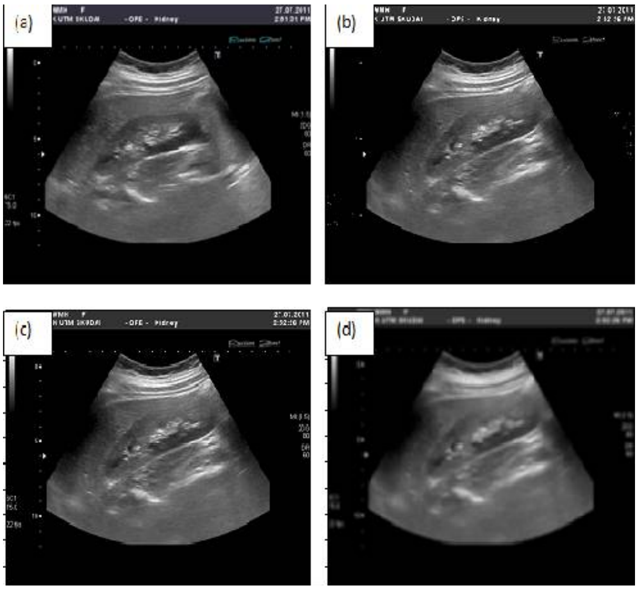

Figure 1 (a) Original Ultrasound kidney image (b) Median filtered kidney image (c) Wiener filtered kidney image (d) Gaussian low-pass filtered kidney image

The simulations are performed in MATLAB. Figure 1 shows the results of various filtering techniques. Figure 1 (a) shows the original ultrasound kidney image. Figure 1 (b) and (c) shows the results of median filtering and Gaussian low pass filtering output. From the output images we identified that wavelet filter gives the best enhancement result among other filtering techniques which are analyzed.

VI. CONCLUSION

There are many ultrasound image enhancement techniques are suggested as spatial domain and frequency domain based techniques. In this paper, ultra sound image enhancement techniques based on Wiener filter, Median filter, Wavelet filter and Gaussian low pass filter are implemented and analyzed. The quality is evaluated by using MSE and PSNR. From the experimental result, it is found that wavelet filter gives better PSNR value. Hence more researchers are focusing on wavelet filtering.

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