ANALYSIS OF RENAL CALCULI IN ULTRASOUND IMAGE USING MATLAB

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ABSTRACT—*This paper proposes an approach to obtain the renal calculi image clearly from ultrasound machine using MATLAB software. In medical image processing, medical images are corrupted by different type of noises. Removing of noise from medical images is now a very challenging issue in the field of medical image processing. Ultrasound imaging is most widely used imaging technique compare to x-ray, MRI and CT scan because of its noninvasive nature, low-cost and capability of forming real time imaging. The major problem of ultrasound imaging technique is inheritance of Speckle noise. Speckle noise tends to reduce the image contrast and blur image details, thereby decreasing the quality and reliability of medical ultrasound. As a result, image processing methods for Restoration or reduction of speckle noise from ultrasound images has become the predominant step in medical image processing. Many de-noising methods such as Mean filter, Median filter Lee filter, Kuan filter, Frost filter and Diffusion filters have been developed for de-speckling of ultrasound images. Then, the filtered images were measured using Mean Square Error (MSE), Root Mean Square Error (RMSE), Signal to Noise Ratio (SNR),Power Signal to Noise Ratio (PSNR), Average Difference (AD), Speckle Index(SI) formula to know which types of filter produce best quality images.*

Key Words: Ultrasound Image, Speckle Noise, De-speckling Filtering

1 INTRODUCTION

The medical diagnostic using ultrasounds became intensive used since the early 1980s, but scanner cost and spatial dimensions has limited its use to hospital settings for decades . From the middle of 1990s, several manufacturers offered portables ultrasound machines. The ultrasound image is obtained using ultrasonic waves in 3 to 20 MHz range. The medical name for kidney stones is renal calculi. The stones can form in lower calyx, pelvis of the kidney, ureter and bladder. Kidney is the main organ of the urinary system. Kidney does not make only urine but also it purifies blood. It has two basic functions- Disposing toxic substances from the blood and retains the useful components in proper balance[4].

Ultrasound imaging has become a popular modality because it is safe, noninvasive, portable, relatively inexpensive, and provide a real time image formation. However, the fundamental problem of ultrasound image is the poor quality , mainly caused by multiplicative speckle noise. Speckle is a complex phenomenon, which degrades image quality with a backscattered wave appearance which originates from many microscopic diffused reflections those pass through internal organs and makes it more difficult for the observer to discriminate fine detail of the images in diagnostic examinations. The acquired image is thus corrupted by a random granular pattern that delays the interpretation of the image content and reduces ability to detect the features of interest Speckle degrades the quality of Ultrasound images and them reducing the ability of a human observer to discriminate the fine details of diagnostic examination[4]. Besides, due to the presence of speckles in ultrasound images, the enhancement of US image is extremely difficult especially in image of liver and kidney whose underlying structures are too small to be resolved by large wavelength So, before making any image analysis, suppressing the speckle noise and enhancing the image without losing valuable image features is a very important step.

2 IMAGE ENHANCEMENT

Image enhancement is the process of manipulating an image so that the result is more suitable than the original for a specific application. Image enhancement refers to the sharpening of image features such as boundaries or contrast to make the graphic display more useful for display and analysis. Image enhancement is used to enhance the perception of information in images for human viewers and provide a better predictive view for currently image processing techniques[2 3]. The enhancement process can be categorized and can be divided into spatial domain filtering, morphological filtering, histogram equalization, frequency domain Gaussian low pass filtering . In this study, we use Mean, Median, Lee, Frost, filter for enhancement and smoothing process[4].

3 DESPECKLE FILTERING TECHNIQUES

Despeckle filtering techniques for ultrasound imaging, grouped under the following categories, linear filtering, nonlinear, anisotropic diffusion filtering, and wavelet filtering. Filtering is the preprocessing step for noise reduction before image enhancement. Some neighborhood operations work with the values of the image pixels in the neighborhood and the corresponding values of a sub image that has the same dimensions as the neighborhood[3]. The sub image is called a filter, mask, kernel, template, or window, with the first three terms being the most prevalent terminology.The values in a filter sub image are referred to as coefficients, rather than pixels. Spatial filtering consists simply of moving the filter mask from point to point in an image.

3.1 Mean filter

Mean filtering is most commonly used as a simple method for reducing noise in an image. The Mean filter is a linear filter which uses a mask over each pixel in the signal. Each of the components of the pixels which fall under the mask are averaged together to form a single pixel. The mean filter is a simple sliding-window spatial filter that replaces the center value in the window with the average (mean) of all the pixel values in the window.

3.2 Median filter

The median filter is a nonlinear digital filtering technique, often used to remove noise . Such noise reduction is a typical pre-processing step to improve the results of later processing for example, edge detection on an image. Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise.

3.3 Frost filter

The Frost filter replaces the pixel of interest with a weighted sum of the values within the NxN moving kernel. The weighting factors decrease with distance from the pixel of interest. The weighting factors increase for the central pixels as variance within the kernel increases.

The filter output is determined by

$$I_s = \sum_{p \in n_s} m_p I_p$$

Where,

$$m_p = \exp\left(-KC_s^2 d_{s,p}\right) / \sum_{p \in n} \exp\left(-KC_s^2 d_{s,p}\right)$$

$$d_{s,p} = \sqrt{(i - i_p)^2 + (j - j_p)^2}$$

Where K is the damping factor, (i, j) are the grid coordinates of pixel s, and (ip,jp) are those of pixel p. The factor K is chosen such that when in a homogeneous region KC_s^2 approaches zero, yielding the mean filter output; at an edge KC_s^2 becomes so large that filtering is inhibited completely.

3.4 Lee filter

Lee filter is an adaptive type filters. It is used for speckle noise reduction. Lee filter is based on the assumption that the mean and variance of the pixel of the interest is equal to the local mean and variance of all pixels within the moving kernel. Lee filter generate their output images by computing a linear combination of the center pixel intensity in the filter window with the average intensity of the window. Lee filter combines an efficient noise reduction while maintaining the sharpness and some characteristics or useful information of the image[3].

Based on a linear speckle noise model and the minimum mean square error (MMSE) design approach, the filter produces the enhanced data according to

$$I_s = I_s + K_s(I_s + \bar{I}_s)$$

Where is the mean value of the intensity within the filter window ns and ks is the adaptive filter coefficient determined by

$$K_s = 1 - C_u^2 / C_s^2$$

Here,

$$C_s^2 = (1/n_s) \sum_{p \in n} (I_p + \bar{I}_s)/(I_p + \bar{I}_s)^2$$

and C_s^2 constant for a given image and can be determined by either,

$$C_s^2 = 1/ENL \quad \text{Or,}$$

$$C_u^2 = \frac{var(z')}{(\bar{z'})^2}$$

3.5 Kuan filter

Kuan filter also smoothes the image without removing edges or sharp features in the images. The Kuan filter has the same form as the Lee filter but with a different weighting function. Kuan filters are used to reduce speckle while preserving edges in images. It transforms the multiplicative noise model into a signal dependent additive noise model. Different filter sizes will greatly affect the quality of processed images. If the filter is too small, the noise filtering algorithm is not effective. If the filter is too large, sub details of the image will be lost in the filtering process. The resulting filter has the same form as the Lee filter but with a different weighting function.

3.6 SRAD filter

SRAD technique is based on a partial differential equation (PDE) and the MMSE, which can be related directly to the Lee and Frost window-based filters.Thus, according to the PED, the equation of the SRAD can be briefly described as follows:

$$\frac{\partial I(x,y;t)}{dt} = div[c(q)\nabla I(x,y;t)]$$

$$I(x,y;0) = I_0(x,y;0), (\partial I(x,y;t)/\vec{n})|\partial\Omega = 0$$

where $I0(x, y)$ represents the intensity image, $I(x, y;t)$ is the output image, 'div' the divergence operator, $\partial\Omega$ denotes the border Ω, $\vec{n}$ is the outer normal $\partial\Omega$, and $C(q)$ is the diffusion coefficient and can be calculated as follows:

$$C(q) = \frac{1}{1 + [q^2(x,y;t) - q_0^2(t)]/[1 + q_0^2(t)]}$$

where $q(x, y; t)$ is the instantaneous coefficient of variation determined by:

$$q(x,y;t) = \sqrt{\frac{\left(\frac{1}{2}\right)\left(\frac{|\nabla I|}{I}\right)^2 - \left(\frac{1}{4^2}\right)(\nabla^2 I/I)^2}{1 + \left(\frac{1}{4}\right)(\nabla^2 I/I)^2}}$$

where ∇ is the gradient operator, || denotes the magnitude.The coefficient $q0(t)$ is estimated below

$$q_0(t) = \frac{\sqrt{var|z(t)|}}{\overline{z(t)}}$$

where $var[z(t)]$ and $z(t)$ are the intensity variance and mean over a homogeneous area at t, respectively.

3.7 PMAD filter

Perona and Malik proposed a nonlinear anisotropic diffusion filter to avoid the blurring original image and localization problems of linear diffusion linear filtering, It is called Perona-Malik Anisotropic Diffusion (PMAD) filter.Anisotropic diffusion is widely used as a multi-scale nonlinear image processing technique that offers a good compromise between noise removal and edge preservation. Perona and Malik replaced the classical isotropic diffusion equation, as described above, by the introduction of a function dij,t = f ($|\nabla g|$) that smooths the original image while trying to preserve brightness discontinuities with

$$\frac{dg_{ij,t}}{dt} = div[d_{ij,t}\nabla g_{ij,t}]$$

$$= \left[\frac{d}{di}d_{ij,t}\frac{d}{di}d_{ij,t}\right] + \left[\frac{d}{dj}d_{ij,t}\frac{d}{dj}d_{ij,t}\right]$$

where $|\nabla g|$ is the gradient magnitude, and $d(|\nabla g|)$ is an edge stopping function, which is chosen to satisfy $d \rightarrow 0$ when $|\nabla g| \rightarrow \infty$, so that the diffusion is stopped across edges.

4 PERFORMANCE PARAMETERS

Performance parameters are represented as a data that used to evaluate the imaging systems or processing techniques. The most frequently and famous used measures are deviations between the coded and original images. The mean square error (MSE) or signal to noise ratio (SNR) is usually used for image quality measurement. In this study, we use MSE, PSNR, RMSE, SNR, SI, and AD formula to measure the quality of images.

4.1 Mean Square Error (MSE)

MSE is measures how accurately each individual input sample can be recovered using the channel output. The MSE equation can be expressed as following formula

$$MSE = \frac{1}{MN}\sum_{J=1}^{M}\sum_{K=1}^{N}(X_{J,K} - X'_{J,K})$$

where m×n is the resolution of frames, $X_{J,K}$ is an original images and $X'_{J,K}$ is noisy images.

4.2 Root Mean Square Error (RMSE)

The root mean square error (RMSE) is used to find the total amount of difference between two images. It indicates the root of average difference of the pixels throughout the image. It can be shown as follows

$$RMSE = \sqrt{\frac{\sum(X'_{j,k} - X_{j,k})^2}{MN}}$$

where $X_{J,K}$ is an original images and $X'_{J,K}$ is noisy images.

4.3 Signal-to-Noise Ratio (SNR)

A common way to evaluate the noise suppression in the case of multiplicative noise in coherent imaging is to calculate the signal-to-noise (SNR) ratio, defined as:

$$SNR = 10\log_{10}\frac{\sum(X_{j,k})^2}{\sum(X'_{j,k} - X_{j,k})^2}$$

where $X_{J,K}$ is an original images and $X'_{J,K}$ is noisy images.

4.4 Peak Signal to Noise Ratio (PSNR)

PSNR is a ratio represented between the maximum possible value (power) of a signal and the power of distorting noise. It would effects on the quality of its representation. It can be shown as follows

$$PSNR = 10\log[2^n - 1]^2/MSE$$
$$= 10\log 255^2/MSE$$

where n is denoted the nth frames.

4.5 Average Difference (AD)

AD is useful to measure the statistical dispersion. It means that the measurement is equal to the average absolute difference of two independent values that coming from a probability distribution. Average difference equation is denoted as follows

$$AD = \sum_{J=1}^{M}\sum_{K=1}^{N}\frac{X_{J,K} - X'_{J,K}}{MN}$$

where m×n is the resolution of frames, $X_{J,K}$ is an original images and $X'_{J,K}$ is noisy images.

4.6 Speckle Index (SI)

SI is a measure of speckle reduction in terms of average contrast of the image. Lower value of SI corresponds to improved image quality. The SI is defined as follows:

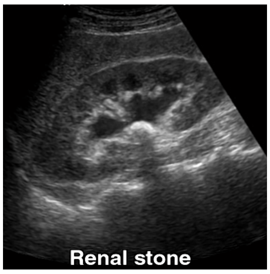
following formula

$$SI = \frac{1}{MN}\sum_{J=1}^{M}\sum_{K=1}^{N}\frac{\sigma(i,j)}{\mu(i,j)}$$

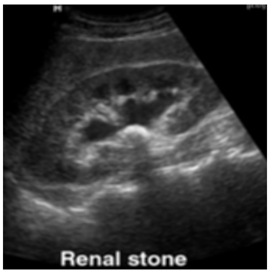
where σ(i, j) and μ(i, j) are the standard deviation and means corresponding to a neighbour domain, respectively.

5 SIMULATION RESULTS

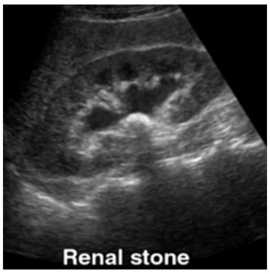
Original Image



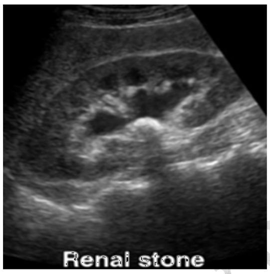
Mean Filter



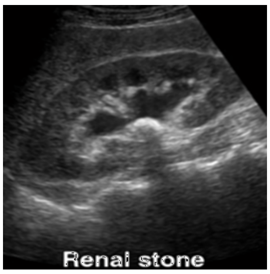
Lee filter



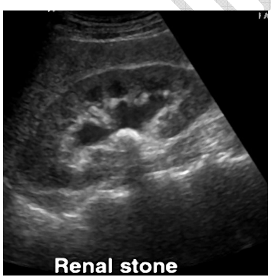
Frost Filter



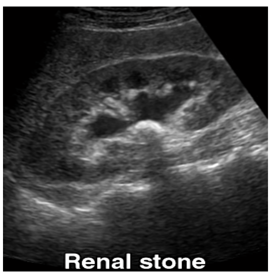
Kuan Filter



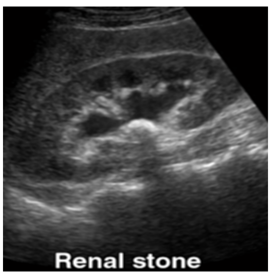
Median filter



SRAD Filter



PMAD Filter



Comparison of Different Parameters of De-Noising Filters (Note: The SI Value of Original Image Equals 3.36796e-06)

Table 1

Filters	RMSE	SI	AD
Median	14.8089	3.2880e-06	0.4005
Mean	15.9549	3.0116e-06	0.0139
Frost	19.4374	3.0842e-06	0.1964
Lee	10.8800	3.1576e-06	0.0407
Kuan	11.9783	3.2033e-06	0.4590
SRAD	10.300	3.1538e-06	1.0267
PMAD	8.3914	3.1548e-06	0.0391

Table 2

Filters	MSE	SNR	PSNR
Median	219.3038	8.2862	24.7203
Mean	254.56	7.7543	24.0729
Frost	377.8117	4.5572	22.3580
Lee	118.3747	10.3343	27.3982
Kuan	143.4804	10.2251	26.5629
SRAD	94.9938	13.0963	47.8743
PMAD	70.4159	16.0679	29.6541

6 CONCLUSION

In this Paper for enhancement and restoration of Medical ultrasound imaging from the experimental and mathematical results on different techniques for restoration of Medical ultrasound images it can be concluded that spatial domain filtering methods such as Mean Filter, Median Filter, Lee filter ,Frost filter and Kuan filter remove noise but important diagnostic details are lost. Wavelet based techniques gives better results but they fail to perform well near edges. PDE based SRAD and PMAD filter gives better de-noising and with edge prevention but it require more iteration to reach convergence.

In order to select the best image, we used several filters method and make a calculation process includes Mean Square Error (MSE), Root Mean Square Error (RMSE),Signal to Noise Ratio(SNR), Power Signal to Noise Ratio (PSNR), Average Difference (AD),Speckle Index(SI) to see the quality of images after filtering process. Unfortunately, we cannot clearly differentiate renal calculi in ultrasound images before and after filtering process using human eyes but we can see it through the data comparison between various calculation as mentioned earlier.Shows the result of data comparison between different filters method in term of image quality measurements. All the data was calculated by using MATLAB R2013a software.

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