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Speckle Noise Reduction in Ultrasound Images for Chronic Kidney Disease Detection

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Abstract **– In the field of biomedical imaging, the ultrasound imaging is a vital tool for diagnosis of various disease or abnormalities. Unfortunately, the presence of speckle noise in these images affects edges and fine details which limit the contrast resolution and make diagnostic more difficult. Hence speckle noise reduction is an important task for developing a effective diagnosis system. In this paper various filtering techniques are presented for removal of speckle noise from Ultrasound images for detection of Chronic Kidney Disease.**

Keywords **- Abnormalities, Chronic Kidney Disease, Resolution, Speckle Noise, Ultrasound Image.**

I. Introduction

In the last few decades, several non-invasive new imaging techniques have been discovered such as X-ray, CT scan, MRI, SPECT, ultrasound, and others. All these imaging devices are producing abundant images which are used by doctors for diagnosis. The main problem faced by doctors is the noise introduced due to the coherent nature of the ultrasound echoes. These noises may corrupt the image and often making diagnosis difficult. Each of these medical imaging devices is affected by different types of noise like x-ray images are often corrupted by Poisson noise, while the ultrasound images are affected by Speckle noise. Speckle is a complex phenomenon, which degrades image quality with backscattered echoes which originates from many microscopic diffused reflections that passing through internal organs and makes it more difficult for the doctor to distinguish fine detail of the images. Thus, denoising or reducing these speckle noise from a noisy image has become the most important step in medical image processing [1]. Multi-look process and spatial filtering are the two techniques of reducing speckle noise. Multi-look process is used at the data acquisition stage while spatial filtering is used after the data is stored. Among the two any method can be used to remove the speckle noise, but they should preserve radiometric information, edge information and spatial resolution. These conditions are met by speckle noise reduction technique [2].

Speckle may appear distinct in different imaging systems but it is always represented in granular pattern due to Image formation under coherent waves. Speckle reduction is a critical pre-processing step for extraction of features analysis and recognition from ultrasound image measurements [3]. This paper is organized as follows: Section II presents Model of speckle noise. In Section III, Speckle reducing filters for ultrasound images are discussed. Data and results are discussed in section IV. Section V presents conclusions.

II. Model of Speckle Noise

An inherent characteristic of ultrasound imaging is the presence of speckle noise. Speckle noise is "a random, deterministic, interference pattern in an image formed with coherent radiation". Speckle has negative impact on ultrasound imaging, Radical reduction in contrast resolution may be responsible for the poor effective resolution of ultrasound as compared to MRI [3] [4]. In case of medical literatures, speckle noise is also known as texture. Generalized model of the speckle noise is represented as,

$$f(x,y) = g(x,y).\eta_m(x,y) + \eta_a(x,y) \quad (1)$$

Where, $f(x,y)$ is the real noisy image, $g(x,y)$ is an unknown noise free image. η_m and η_a are multiplicative and additive noise functions. Since additive noise is considered to be lower than multiplicative noise, so additive component of the noise is to be ignored [5]. Hence equation (1) can be modified as,

$$f(x,y) = g(x,y).\eta_m(x,y) \quad (2)$$

The basic block diagram for speckle noise reduction is shown in Figure 1. For speckle noise reduction in ultrasound images following process is carried out. As shown in Figure noisy image of USG is applied to denoising filter as input. In denoising filter various filter like median, ideal and butterworth are used to suppress the speckle noise. After suppressing speckle noise we get denoised image as output image.

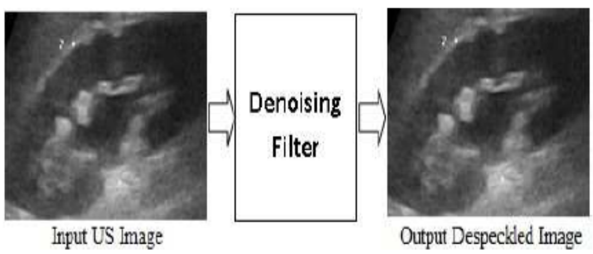

Fig.1. Basic Blocks of Speckle Noise Reduction

III. Speckle Reducing Filters for Ultrasound Images

This paper deals with characteristic type of noise called speckle noise. The images with this type of noise display a granular pattern due to the dispersion of the ultrasound waves caused by the transducer. This noise is very harmful since it limits the detection of injuries especially in low contrast images. So denoising techniques plays very important role in this study of region detection between renal pelvis and parenchyma. This is useful for detection of chronic kidney disease. Different types of filters are available for denoising ultrasound image. In this paper Median filtering, types of Fourier filtering techniques are discussed.

A. Median filtering

It is a non linear filter applied to an image special domain. The median filter is often effective for speckle reduction. The median filter works by moving through the image pixel by pixel, replacing each value with the median value of neighbouring pixels. The pattern of neighbours is called the "window", which slides, pixel by pixel over the entire image.

The median is calculated by first sorting all the pixel values from the window into numerical order, and then replacing the pixel being considered with the middle (median) pixel value. It uses the median intensity in suitable sized and shape region $Wi\ j$ surrounding the pixel (i, j) of interest as the output pixel value; hence it eliminates any impulsive artifact with an area less than half the region size $||Wi\ j||$. For this method different window sizes 3,5,7,9 and 11 are available. A median filter with 3x3 window size eliminates noise in such a way that we obtain a better quality image than the noisy image. This tendency continues as the window size increases.

When a small window size 3x3 is used, some of the noise disappears without losing important details. If the size of window is increased to eliminate more noise we get counterproductive effect which results in loss of edges. Small details in the image can also disappear [6].

B. Fourier filtering

Fourier filtering is naturally based on Fourier transform properties. In this type of filtering it minimizes Fourier transforms high frequency components. Once this is done the output image will be obtained by means of the inverse Fourier transform. Two types of filters, Ideal filter and Butterworth filter are used in this paper.

1) Ideal Filtering: This filter cuts off all high frequency components of the Fourier transform that are at a distance greater than a specified distance D0

$$H(u,v) = \begin{cases} 1, & D(u,v) < D0 \\ 0 & otherwise \end{cases} \quad (3)$$

In this filter cut off frequency is set at 10%. By experimenting, the noise in some part of background is smoother but the object contours have become blurred and there is a wave effect. This is known as "Gibbs Effect". If Cut-off value lowered even more we get greater smoothness but we also lose sharpness in the image and Gibbs effect become more significant. So we do not lower cut off frequency any more [6][7].

2) Butterworth Filtering: As stated in ideal filtering, the Gibbs effects are due to the sharp cut-off in the Ideal filter and to get rid of this effect, we need to eliminate these sharp cut-offs. The transfer function of Butterworth low pass filter of order n and cut-off frequency at a distance D0 from the origin is defined as

$$H(u,v) = \frac{1}{1+[D(u,v)/D0]^{2n}} \quad (4)$$

As the order of the filter goes on increasing a small amount of ringing effect does creep in because Butterworth low pass filter tends to be an Ideal filter[6][7].

IV. Data and Results

To compare all these filtering techniques for chronic kidney disease detection, kidney images are used. As shown in Figure 2 the images are generated by applying median filter of window size (3x3), (4x4), (7x7), (9x9) and (11x11). We can see gradually as window size increases, the image gets smoother and color get more uniform. From Figure 2 (e) and (f) it seems that as window size increases, the border gets more and more blurry.

For performance evaluation noisy image is generated first. The metrics used to experiment with this kidney images are Mean Square Error (MSE), Peak Signal-to-noise ratio (PSNR). The values obtained from the metrics for noisy images are presented in Table I and metrics for median filtered image of window size 4x4 presented in Table II. Images generated by applying Ideal filter with cut-off frequency 10%, 30%, and 50% are shown in Fig.3.

Also images generated by applying Butterworth low pass filter with cut off frequency 10%, 30% and 50% with order of filter two are shown in figure 4 .

Table I: Metrics Value For Noisy Image

Sr.No	MSE	PSNR
Image 1	193.73	25.29
Image 2	176.74	25.69
Image 3	193.79	25.29

Table II: Metrics Obtained When Applying the Median Filter Window Size 4x4

Sr.No	MSE	PSNR
Image 1	99.51	28.19
Image 2	98.61	28.19
Image 3	90.28	28.57

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V. Conclusion

In this paper techniques for speckle noise reducing from ultrasound images are discussed. This will help further for more accurate segmentation and classification of chronic kidney diseases. Median filter, Ideal filter and Butterworth filter are used for speckle noise removal. Median filter with window size (4x4) provides better results than window size of (3x3), (5x5), (7x7). Ideal filter is much simpler than any other filter because it takes only one parameter. Butterworth filter takes order of filter and cut-off frequency as two parameters. It eliminates Gibbs effect produced by Ideal filter. For the detection and classification of chronic kidney diseases, median filter with window size (4x4) gives better results than other filters and is used for further processing.

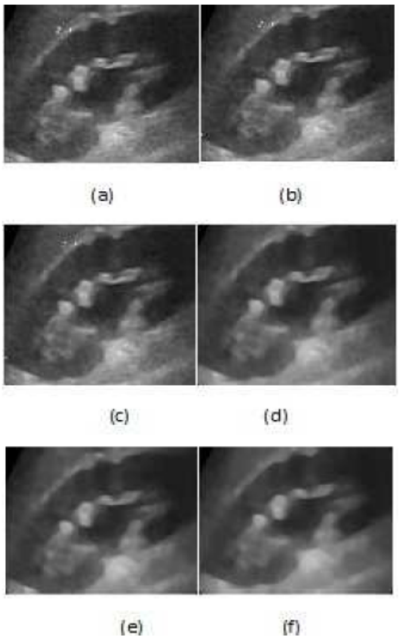

Fig.2. Images after applying the median filter with different window size (a) original Image (b)3x3 window (c)4x4 window (d) 7x7 window (e) 9X9 window.(f) 11X11 window

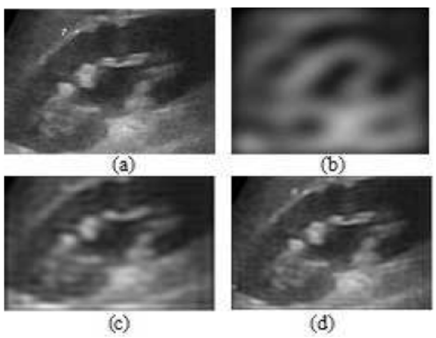

Fig.3. Images after applying the Fourier Ideal filter with different cutoffs. (a) Original Image (b) 10% cutoff (c) 30% cut off (d) 50% cutoff

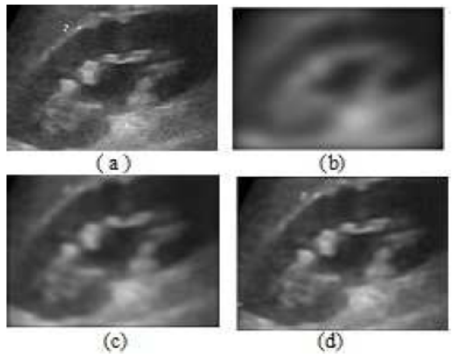

Fig.4. Images after applying the Butterworth filter with different cutoffs. (a) Original Image (b) 10% cutoff (c) 30% cut off (d) 50% cutoff.

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