Image Denoising Techniques: A Review

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Abstract

Medical images or ultra sound images are mostly used in the medical field for many purposes. Many problems occurred in the medical images. Main problem related to this imaging technique is introduction of speckle noise which blurs or degrades the quality of the image. Speckle noise makes the image unclear which is tuff to see clearly. There have been several techniques to de-noise the speckle noise from the images. This paper presents a case study of some different techniques which reduce the speckle noise from image.

Keywords: medical images, speckle noise, speckle filter, image de-noising, wavelet transform.

1. Introduction

Medical images or ultra sound imaging are inexpensive, real time and non radioactive. Medical images are like x- rays in which you see your fractures and other injuries clearly. If the speckle noise occurs in the image then we will not see the image clearly. Image will be unclear or degraded by the speckle noise. Speckle noise reduces the resolution, contrast and important information. Reducing the speckle noise however still remains a challenge because due to the use of the de-noising techniques it cause the blurring of the medical image[1].So mostly the physicians uses the original noisy image rather than the filtered. Because sometimes the necessary information is lost when de-noising of the image is done. So the original noisy image is preferred. Speckle noise is multiplicative in the nature within each resolution cell a number of elementary scatterers reflect the incident wave towards the sensor. The back scattered wave with different phases undergo constructive or destructive interference in a random manner and then the required image is corrupted by the noise called speckle which delays the interpretation of the image content which occurs not clear. Speckle noise shows in the following manner because it is multiplicative in the nature:

$$g(x,y)=f(x,y)*n(x,y)$$

Where n(x,y) is the multiplicative in the nature.

Speckle Noise Modeled as Follow:

$$v_1=f_1V$$

$f= \{f_1,f_2,f_3 \ldots\ldots f_n\}$ is a noisy free ideal image.

$v=\{v_1,v_2,v_3 \ldots\ldots v_n\}$ is speckle noise.

$V = (v_1, v_2, v_3 \ldots\ldots v_n\}$ is a unit mean random field.[2]

The paper is organized as follow: In section 2 some de-noising techniques or de-speckling techniques are discussed. In section 3 explains the wavelet based filtering techniques and in the section 4 we will discuss about the various de-noising or de-speckling techniques: Median filter, wiener filter, lee filter, kuan filter, frost filters are the de-speckling techniques.

2. Standard de-speckling techniques

There are many speckle reduction filters available, some give better visual interpretations while others have good noise reduction or smoothing capabilities. Some of the best known speckle noise reduction filters are median wiener filter, lee filter, kuan filter and frost filters.

Some these filters are based on spatial filtering in a square moving window known as kerne .It works only on the centre pixel and its surrounding pixels. The size of the filter window can range from 3 by 3 to 33 by 33, but the size of the window must be odd. If the size of the window will too large then the important information will be lost due to over smoothing and if the size of the window is too small then it will not give the good results. Mostly 3 by 3 or 7 by 7 is used as it gives good results [3].

2.1 Median filter

The median filter works on the centre pixel means. It works by moving through the image pixel by pixel, replacing each value within the median value of neighboring pixel. The pattern of neighbors is called window, which slides pixel by pixel, over the entire image. The median is calculated by first sorting all the pixels values from the window into the numerical order, and then replacing the pixel being considered with the middle pixel value. It is non linear filtering technique. It is specially used to remove the salt and pepper noise. It is effective in the strong spike components and the characteristics to be preserved are edges. The main disadvantages of the median filter is that it takes lots of time and the extra computation time needed to sort the intensity value of each set [9].

2.2 Wiener filter

Wiener filter also known as least mean square filter. Wiener filter proposed in the year of 1942 is adaptively applied on the image according to the variance. It minimizes the overall mean square error in the process of inverse filtering and noise smoothing. It is the linear estimation of the original image [10]. If the variance is small, wiener performs smoothly; if the variance is large then the wiener performs less smoothly. This approach gives the better result than the linear filters. Wiener filter gives the following expressions:

$$f(u,v) = \left[\frac{H(u,v)*}{H(u,v)^2 + \left[{Sn(u,v)}/{Sf(u,v)}\right]}\right] G(u,v)$$

(1)

$H(u,v)^2$ is the degradation function and $H(u,v)^*$ is the conjugate complex. G(u,v) is the degraded image. Functions $S_1(u,v)$ and

$S_n(u,v)$ are power spectra of original image and the noise[3].

2.3 Kuan filter

Kuan Filter is a local linear filter. Kuan filter is multiplicative in nature. It is the minimum square error filter based on the multiplicative order and it does not make any approximation on the noise variance within the filter window like lee filter. It is multiplicative model of the speckle noise in the additive linear form. It has a weighted function which is calculated as follows:

$W=(1-C_u/C_i)/(1+C_u)$

And the C_u is calculated by this expression:

$C_u=\sqrt{1/ENL}$

And C_i is the variation coefficient of the image calculated as follow:

$C_i=S/Im$

Where S is the standard deviation in filter window and Im is mean intensity value with in the window.

The main disadvantage of the kuan filter is that the ENL parameter is needed for computation [4].

2.4 Frost filter

Frost filter replaces the pixel of interest with the weighted sum of the values within the n×n moving kernels. The weighting factor decreases with distance from the pixel of interest. The weighted factor increases for the central pixels as variance with in the kernel increases. Frost filter is a spatial domain adaptive filter that is based on multiplicative noise order. Frost has following expression:

$DN=\Sigma_{n\times n}K\alpha e^{-\alpha}|t|$

Where $\alpha=(4/n\sigma^2)(\sigma^2/I^2)$

K=Normalization constant

I=local mean

σ=local variance

σ^-=image coefficient of variation value.

$|t|=|X-X_0|+|Y-Y_0|$

n=moving kernel size [5].

2.5 Lee Filter

Lee filter basically used for speckle noise reduction. The lee filter is based on the assumption that mean and the variance of the pixel of the interest is equal to the local mean and the variance of all pixels within the moving kernel. Lee filter is based on the variance. If the variance of the area is low or constant, then smoothing will not be performed, otherwise smoothing will be performed.

$Img(i,j)=im+W*(Cp-Im)$ (2)

Where the pixel value at indices i,j after filtering, im is mean intensity of the filter window.

$W=\sigma^2/(\sigma^2+\rho^{2)}$ (3)

σ^2 is the variance of the pixel within the filter window and is calculated as:

$\sigma^2=[1/N\,\Sigma_{j=0}^{N-1}(x_j)^2]$ (4)

N is the size of the filter window and X_J is the pixel value within the filter window at indices j.

$$P^2=[1/M\,\Sigma_{i=0}^{M-1}\,(Y_i)^2 \qquad (5)$$

The parameter ρ is the additive noise variance of the image in following equation, where M is the size of the image and Y_j is the value of each pixel in the image.

3. Wavelet Filters

3.1 Wavelet Denoising Technique

There are several denoising techniques to reduce the speckle noise with using the wavelets.

Wavelet noising filtering: we will use the wavelet noise thresholding which is Discrete Wavelet Transform (DWT). In the case of DWT first the image is divided into the four parts HH, HL, LH, and LL and the further the approximation part is divided into two sub-bands. Approximation part is LL. And the other part is detailed part in which we have all three parts HH, HL and LH. We will work on the detailed part because the noise will occur on the high frequency part which is detailed part.

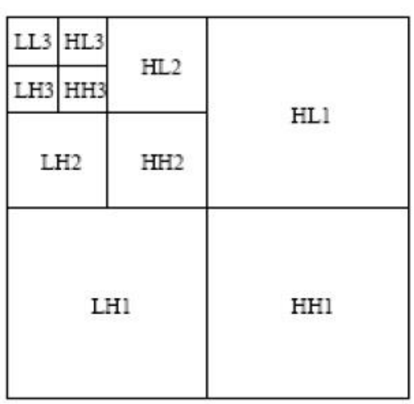

FIG: Two level image thresholding decomposition by using DWT [8]

DWT is used to reduce the speckle noise from the image. It has three steps which are given below:

1. Calculate the DWT of the image.

2. Threshold the wave coefficients.

3. Compute the IDWT to get the denoised image.

Two types of thresholding functions are there soft and hard thresholding. Soft thresholding reduces or deletes the high frequency components in which speckle noise is present but it also loses some needed information. Soft thresholding function described as follow:

$n_2\,(w)=(w\text{-}sgn(w)T)I(w|w|>T)$

where sgn (x) is the sign function of x. The soft thresholding is preferred over the hard thresholding rule.

Hard thresholding reduces or deletes the low frequency components which also lose the some necessary information. Hard thresholding is described as follow: $n_1(w)=wI(|w|>T)$ where w is a wavelet coefficient, T is the threshold[2][6][7].

4. Discussion

We have studied various types of de-speckle filters and wavelet based technique. The wavelet techniques outperforms the best result better than the other filter techniques because all other filters have some disadvantages due to which those filters not able to reduce the speckle noise properly from the medical image. In the case of the wavelet based technique DWT it is better than all of the other filters for reduction of the speckle noise. Standard filters perform well on the ultra sound images but they have some constraints regarding resolution degradation. These filters are based on the fixed window which is placed on the specific part and then is moved to the next part and then work on that part. Some filters cause over-smoothing which loses the needed information. Wavelets are best because it has the properties like multi-resolution, multi-scale and sparsely nature.

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