Speckle Reducing Filtering for Ultrasound images

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Abstract* - Speckle noise is undesired result which appear during the image formation process in that is most typically known to occur in the coherent imaging systems for example ultrasound imaging, sonar, lasers, synthetic aperture radar and many more. So the presence of speckle in ultrasound imaging system results in decrease in quality of image and it become quite difficult for human to diagnose and interpret the change with naked eyes. Thus in case of analysis of ultrasound images speckle reduction is done to reduce unwanted noise in image. Till now numerous methods are proposed for speckle reduction or speckle suppression. So our approach is to brief the speckle noise reduction model by using various speckle reduction filters. Different filters have different behavior as some keep the content in the image while others provide the smoothening process. Similarly some are better for edge detection and can be applied for tumor segmentation etc. In the end, we have provided some commonly used filter assessment techniques.

***Keywords**: frost, kuan , speckle noise, ultrasound, , weiner, wavelets*

1 Introduction

Speckle noise mainly occurs in coherent images. Due speckle noise in imaging system there is reduction in the resolution specially the images which are low contrast. In ultrasound images ,automatic explanation is a tough job due to low SNR ie (signal to noise ratio) . This low SNR is mainly due to speckle noise present in the ultrasound image. The objects which are of similar size to that of sound wavelength are exposed to interference with ultrasound pulses, thus interference pattern is produced . This noise tends to blur the very important information and significantly decreases the image quality. Thus special experience and training is required for explaining ultrasound images. Many times, even very expert sonographers fail to make an appropriate diagnosis of ultrasound images due to noise. Many research work has been done to reduce the speckle noise in ultrasound images in past few years. The first technique with the help of which speckle noise in ultrasound images was reduced is Temporal averaging .

In this technique same scene multiple uncorrelated frames are averaged to reduce the noise effect. This temporal averaging technique is very fast and simple, but it generate blurry image and some of the details are lost. One filter that has been proposed for speckle reduction, uses the weights of surrounding pixels and the filter has been named as AWMF ie Adaptive Weighted Median Filter . In this filter , to suppress the speckle noise weighted median filter is used. , in this weight coefficients are varied around every pixel. After AWMF one more filter has been proposed and it is called ASSF ie Adaptive Speckle Suppression Filter. This filter also uses the same local statistics of ultrasound images.

Here by the help of using appropriate shape and size of local filtering kernels we can achieve the filter adaptation. One also projected a "stick" method so as to find the tissue boundaries and curb the speckle noise. So at every point, so as to get maximum projected value, some variations are done in the orientation of the image. Another speckle reducing filters are given by Lee, Frost and Kuan. Many speckle models are used in these filters but the main motive behind all these filters is similar . In all of them, inside a moving window the extent of variation is evaluated after that it is passed to allow pass filter, this filter smooth’s the regions which have less variation and then again it is fed to a all pass filter and this is used for regions which have high variation. The de-noising performance of these filters are determined from its two parameter one is its shape and another is its size. Even these filters have some limits, they leave speckle at edges as they do not differentiate between the edges of image. So in this paper I have decided to explore the speckle reduction techniques .

2 Speckle noise modeling

Many imaging and vision related application are effected by speckle noise such applications are like SAR i.e. Synthetic Aperture Radar Imaging , Ultrasound imaging , etc. to study the image data it is very important to reduce the speckle noise from image.. Amplitude of the speckle noise can be represented by a function-

$a(x, y) = a_R (x, y) + ja_I (x, y)$,

where a_R and a_I are zero mean, independent Gaussian random variables for every (x, y) with some variance. The intensity field of speckle noise is given as $n(x, y) = |a(x, y)|^2 = a_R^2 + a_I^2$

The image observation model [6] for speckle noise reads:

$$I_o(x, y) = I(x, y) * n(x, y) + \eta(x,y) \ldots (1)$$

where $I_o(x, y)$ is the viewed speckle noise image; I(x, y) is the original image which has no noise and n(x, y) is the Gaussian noise with zero-mean also and η (x, y) is the additive noise of detector. The general observation model gives the following results if the detector's noise becomes zero:

$$I_o(x, y) = I(x, y) * n(x, y) \ldots\ldots\ldots(2)$$

The B-scan images or 2D ultrasound images are very much used in medical field for diagnosis of any health issue problem . Coherent ultrasound waves are used to produce these images , which are transmitted or reflected at fixed frequencies that link with various interference phenomenon causing speckle noise are proposed. Speckle noise can lead to misinterpretation of ultrasound image at the time of diagnosis so it must be minimized to maximum limit. Normally multiplicative natured speckle noise is present in ultrasound images and it is distributed according to Rayleigh's probability density function (pdf), which is given as

$$p(I / I_o) = \frac{I_o}{\sigma^2} \exp(-\frac{I^2}{2\sigma^2}) \ldots. (3)$$

Where I_0 is the viewed ultrasound image contaminated with speckle noise; I is the image that is to be restored; and σ^2 is the speckle noise variance. The elimination of additive noise is much more easier as compare to multiplicative speckle noise. N-look process , homomorphic filtering and spatial averaging is the process used to reduce speckle noise .During acquisition stage, N-Look process is performed and after the image is acquired speckle reduction is performed by using spatial filtering . Example of such filter is Fast Fourier Transform (FFT). The speckle noise in adaptive filters is considered to be stationary but the changes due to target's type are always considered. This filter reduces the speckle noise and preserves the edges . Adaptive filter varies the contrast stretch for each pixel, depending upon the Digital Number (DN). Examples of adaptive filters are Frost , Gamma MAP, Lee-sigma and Lee. The approach of homomorphic filtering is very different in this we tale log of equation (2) . In this first multiplicative speckle noise is converted to additive noise and after that one of the model of additive noise is applied to reduce the noise , and in final steps exponential of image is obtained the image which we get after applying exponential function is the desired image with reduced speckle.

3. Discrete wavelet transform based filtering

For fast computation of Discrete Wavelet Transform many basic algorithms are developed for processing the image , one of the main aspects of processing is image denoising .. Practically, the DWT of an image or 2D-signal is applied along with a pair of quadrature mirror filters among columns and rows alternatively, then down sampling is done in every direction by the factor of 2. Thus after filtering process the image is reduced into 4 subbands which are HH,HL,LL,LH . Thus a major difference can be seen in distribution of energy of wavelet coefficient with just a small change in an image The non-stationary energy distribution is the consequence of the down-sampling operations. This problem of down sampling can be solved by using the RDWT ie Redundant Discrete Wavelet Transform . In DWT based filtering, de-noising methods has been implemented separately for detailed and approximation coefficients. Soft and hard thresh holding has been common process in de-noising using wavelets and different algorithms has been found on it.

4. Speckle reduction using some common filters

Speckle filtering is performed by moving a kernel over each pixel in the image. Normally we choose odd size kernel window and it extent from 3×3 to 15×15.we assume that all these noise models has a multiplicative form.

4.1 Frost filter

Frost filter is based on multiplicative noise order and it is a spatial domain adaptive filter . It is used for reducing speckle in the radar images while preserving the texture information. The major limitation of frost filter is that the parameters are regulated according to variance in each area. Smoothing will occurs if variance is low . Filter's response is represented as below:-

$$R_{(x,y)} = \frac{(\sum P_n * M_n)}{\sum M_n}$$

Where,

$$M_n = \exp\left(-D * \left(\frac{\delta_n}{\mu_n}\right)^2 * T\right)$$

- Pn is the image pixels.
- D is the damping factor, and it is mostly 1.
- Fn is the standard deviation of the filter window.
- n is mean value
- T is the absolute value of the pixel distance between its surrounding pixels and the centre pixel.

4.2 Lee and Kuan filters

Lee filter. It is based on multiple-look processing (a.k.a. multi-look processing). Lee filter is a window based approach and depends upon the variance. Lee filters are better at preserving image sharpness and the detail while it suppresses noise. Lee filter's major drawback is that it ignores the speckle noise in the closest areas of lines and edges . Kuan Filter The filter which is better than lee filter is Kuan filter because in filter window it has no approximation on the noise. In this additive linear form is obtained from multiplicative noise model. However, it rely on the ENL from an image to judge its W i.e weighting function and is similar to Lee filter in functionality. The formula equation for Lee and Kuan has been proposed below

$R_{(x,y)} = (1-W_{(x,y)})\, I_{(x,y)} + W_{(x,y)}\, I_{(x,y)}$......... 4

Where

$I_{(x,y)}$ is the intensity's mean value within the filter window and

$W_{(x,y)}$ is the adaptive filter coefficient determined using:

$$W_{(x,y)} = \begin{cases} 1 - \dfrac{C_b^2}{C_1^2 + C_b^2} & \textit{for Lee} \\ \dfrac{1 - C_b^2 / C_1^2}{1 + C_b^2} & \textit{for Kuan} \end{cases} \qquad 5$$

where, Ci is the variation coefficient of the contaminated image and Cb is the variation coefficient of the noise.

4.3 Weiner filter

Wiener filter: Wiener filter is a filter which help in generating an approximation of the required random process by using LTI i.e linear time-invariant filtering of an obtained noisy signal . This filter reduces the mean square error between the required process and the estimated random process. Local image variance is given by the following expression:

$$f(\mathrm{u,v}) = \left[\frac{H(\mathrm{u,v})}{H(\mathrm{u,v})^2 + [\mathrm{S}_n(\mathrm{u,v}) / \mathrm{Sf}(\mathrm{u,v})]} \right] \quad 6$$

$$f(\mathrm{u,v}) = \left[\frac{H(\mathrm{u,v})}{H(\mathrm{u,v})^2 + [\mathrm{S}_n(\mathrm{u,v}) / \mathrm{Sf}(\mathrm{u,v})]} \right] \quad 6$$

where, H(u,v) is the degradation function and H(u,v)* is its complex conjugate. $S_f(u,v)$ is power spectra of original image and $S_n(u,v)$ is power spectra of noisy image .

5 Conclusion

In coherent images there may be possibility of occurring speckle noise. Resolution of image reduces because of speckle noise presence in the image system. For designing coherent imaging system minimization of speckle noise is of great importance…. This type of noise is found in many vision and image associated applications like synthetic aperture radar imaging , ultrasound imaging, , and many more. To understand image data properly it is very important to decrease the speckle noise. In this paper, we have provided a brief introduction to speckle noise. There are various filters available for reducing speckle noise but some are more popular and has been discussed by various scholars. We have provided a brief review of theses filters. In future, we will explore this topic further and will propose an algorithm for speckle reduction in frequency domain techniques.

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