Reduction of Speckle Noise and Image Enhancement of Images Using Filtering Technique

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Abstract

Reducing noise from the medical images, a satellite image etc. is a challenge for the researchers in digital image processing. Several approaches are there for noise reduction. Generally speckle noise is commonly found in synthetic aperture radar images, satellite images and medical images. This paper proposes filtering techniques for the removal of speckle noise from the digital images. Quantitative measures are done by using signal to noise ration and noise level is measured by the standard deviation.

Keywords: Speckle noise, SNR, SAR, Sampling Enhancement, Ultrasound images.

1. Introduction

Medical images, Satellite images are usually degraded by noise during image acquisition and transmission process. The main purpose of the noise reduction technique is to remove speckle noise by retaining the important feature of the images. This section offers some idea about various noise reduction techniques. Synthetic Aperture Radar (SAR) imagery uses microwave radiation so that it can illuminate the earth surface. Synthetic Aperture Radar provides its own illumination. It is not affected by cloud cover or radiation in solar illumination. ISUKF technique [1], which uses sampling to incorporate the Discontinuity-adaptive Markov random field for the reduction of speckle noise. Context-based adaptive wavelet thresholding [2] method introduced a simple context-based method for the selection of adaptive threshold. Coherent filtering [3], is a speckle noise reduction technique of the ultrasound images. This technique is based on Coherent Anisotropic Diffusion for real time adaptive ultrasound Speckle noise reduction.

In our work, we introduced a novel method which reduces speckle noise in ultrasound images and SAR images, retaining the original content of these images. This method enhances the Signal to Noise ratio and perceives the original features of the images. The paper is organized as follows.

Section II presents the model of speckle noise and noise in ultrasound images as well as noise in SAR images. Novel method is described in section III. Section IV presents some experimental results in both graphical and tabular forms. Section V describes conclusion.

2. Noise Models

2.1 Model of Speckle Noise

An inherent characteristic of ultrasound imaging is the presence of speckle noise. Speckle noise is a random and deterministic in an image. 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. In case of medical literatures, speckle noise is also known as texture. Generalized model of the speckle [2] is represented as,

$$g(n,m) = f(n,m) * u(n,m) + \xi(n,m) \qquad \text{.................. (1)}$$

Where, $g(n,m)$ is the observed image, $u(n,m)$ is the multiplicative component and $\xi(n,m)$ is the additive component of the speckle noise. Here n and m denotes the axial and lateral indices of the image samples.

For the ultrasound imaging, only multiplicative component of the noise is to be considered and additive component of the noise is to be ignored. Hence, equation (1) can be modified as;

$$g(n,m) = f(n,m) * u(n,m) + \xi(n,m) - \xi(n,m)$$

Therefore,

$$g(n,m) = f(n,m) * u(n,m) \qquad \text{..................(2)}$$

2.2. Noise in Ultrasound Images

Ultrasound imaging system is widely used diagnostic tool for modern medicine. It is used to do the visualization of muscles, internal organs of the human body, size and structure and injuries. Obstetric sonography is used during pregnancy. In an ultrasound imaging speckle noise shows its presence while doing the visualization process.

2.3 Medical Ultrasound Speckle Pattern [3]

Nature of Speckle pattern depends on the number of scatters per resolution cell or scatter number density. Spatial distribution and the characteristics of the imaging system can be divided into three classes:

a) The fully formed speckle pattern occurs when many random distributed scattering exists within the resolution cell of the imaging system. Blood cells are the example of this class.
b) The second class of tissue scatters is no randomly distributed with long-range order [3]. Example of this type is lobules in liver parenchyma.

c) The third class occurs when a spatially invariant coherent structure is present within the random scatter region like organ surfaces and blood vessels [3].

2.4 Noise in Synthetic Apertures Radar (SAR) Images

Synthetic Apertures Radar (SAR) technique is popular because of its usability under various weather conditions, its ability to penetrate through clouds and soil [1]. A SAR image is a mean intensity estimate of the radar reflectivity of the region which is being imaged. Speckle noise in such system is to be referred as the difference between a measurement and the true mean value. Degraded image with speckle noise in ultrasound imaging is given by the equation;

$$d(X,Y) = I(X,Y) * S(X,Y)$$

Where, $d(X,Y)$ is the degraded ultrasound image with speckle, $I(X,Y)$ is the original image and $S(X,Y)$ is the speckle noise. Where (X,Y) denotes the pixel location. The multiplicative nature of speckle complicates the noise reduction process [1].

3. Speckle Noise Reduction and Enhancement of SAR and Ultrasound Imaging

3.1 Noise Reduction in SAR Images

Speckle noise reduction in SAR images has been done using described algorithm below. An algorithm which use sampling to introduced the Discontinuity Adaptive Prior and Moment Estimation [1] within the ISUKF framework for speckle noise reduction. The stepwise algorithm is as given below:

1) Do the modeling of the original image $f(m,n)$ with probability density function

$$P(f(m,n)/\hat{f}(m-x,n-y)) = e^{(-\log(1+\eta^2(f(m,n),\hat{f}))} \quad \ldots\ldots\ldots\ldots(3)$$

Where, $$\eta^2(f(m,n),\hat{f} = (\frac{1}{\rho})^2 \sum_{(x,y)} (f(m,n) - \hat{f}(m-x,n-y))^2$$

$$(x,y)\varepsilon \ \{(0,1),(1,0),(1,1),(1,-1)\}$$

2) Do the estimation of mean μ and variance σ^2 using the mathematical model.

$$\mu = \frac{\sum_{l=1}^{\infty} \omega^l z^{(l)}}{\sum_{l=1}^{\infty} \omega^l} \qquad \text{and} \qquad \sigma^2 = \frac{\sum_{l}^{\infty} \omega^l (z^{(l)} - \mu) * (z^{(l)} - \mu)}{\sum_{l}^{\infty} \omega^l}$$

Where, $\omega^l = (p(z^{(l)})/q(z^{(l)}))$, $p(z)$ is the estimation of non-Gaussian probability Density Function, $q(z)$ is the sampler PDF that includes non-zero support of target PDF.

Infinity (∞) is the samples drawn from the sampler PDF "q" which concentrate on the points where $p \geq q$. When $q \geq p$, we can use samples from q to determine estimation under p.

3) Incorporate the observed noise model as;

$$X(m,n)/(m,n-1) = [\mu,1]^T \text{ and } P(m,n)/(m,n-1) = [\sigma^2]$$

4) Calculate sigma points as[1]; $Y(m,n)/(m,n-1) = X^x(m,n)/(m,n-1) * (m,n-1)$

5) Apply the measurement model on each and every sigma points.

3.2 Noise Reduction in Ultra Sound Images

Steps for the speckle noise reduction in ultra sound images are carried out as below.

a. Construct Multiplicative noise model
b. Do the transformation of Multiplicative noise model
c. Do Wavelet transform of noisy image
d. Calculate variance of noise
e. Calculate weighted variance of signal ∂
f. Calculate threshold value λ of all pixels and sub band coefficients
g. Take inverse DWT to do the despeckling of Ultrasound images.
h. Calculate PSNR (peak signal to noise ratio) for the evaluation of the algorithm

Design procedure of the above implementation steps is shown in Fig.1 in the form of flow diagram.

4. Experimental Results

The performance of the method that has been proposed is investigated with various simulations. Denoising is carried out for ultrasound image with Speckle noise of variance σ2 = *0.03, 0.04, 0.05,* using standard speckle filters and introduced filter. For objective evaluation, the signal to noise ratio (*SNR*) of each denoised image has been calculated using Signal to Noise Ratio (SNR), which is defined as

$$PSNR = 10\log_{10}(255^2 / MSE)$$

$$MSE=(1/MN)\Sigma\Sigma\,(X(i, j)-Y(i, j))^2$$

Where *X(i,j) and Y(i, j)* represent the original and denoised image respectively.

The performance of the various denoising methods is compared in Table 1 and we have presented a comparative study of various wavelet filters and standard speckle filters for **U**ltrasound image in terms of PSNR (see fig. 2 to Fig. 9). The performance of Speckle filters such as *Kaun* filter, *Frost* filter, the conventional approach in speckle filtering the homomorphic *Wiener filter* are measured here. We apply Matlab's spatially adaptive Wiener filter. We have done all the simulations in MATLAB tool.

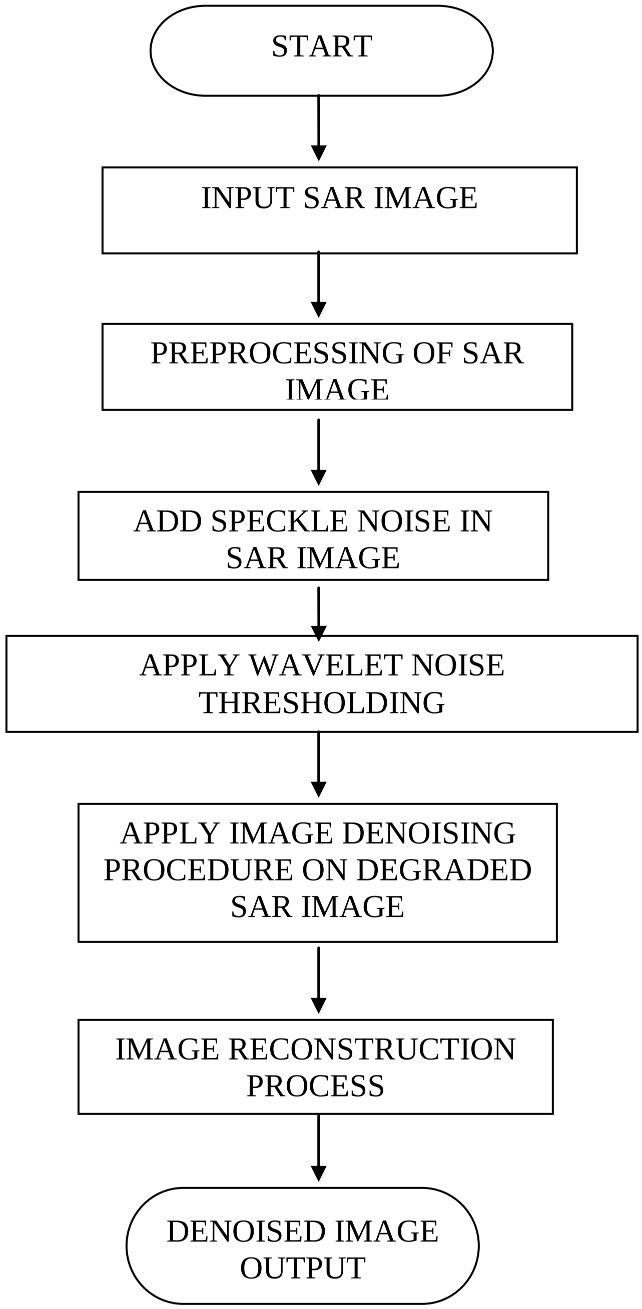


Fig. 1 : Design Procedure of Speckle Noise Reduction

Table 1: Comparison of PSNR of Different De-noising Filters For Ultrasound Images Corrupted By Speckle Noise

σ^2	0.02	0.03	0.04	0.05	0.06	0.07
Frost	22.565	22.045	21.295	20.455	19.615	19.067
Kaun	22.685	22.327	21.583	20.845	20.016	19.126
Visu	31.741	30.823	29.946	28.418	27.221	26.012
Bayes	32.245	31.617	30.833	29.987	28.862	27.564
Proposed	**32.614**	**31.695**	**31.136**	**30.771**	**29.837**	**27.695**

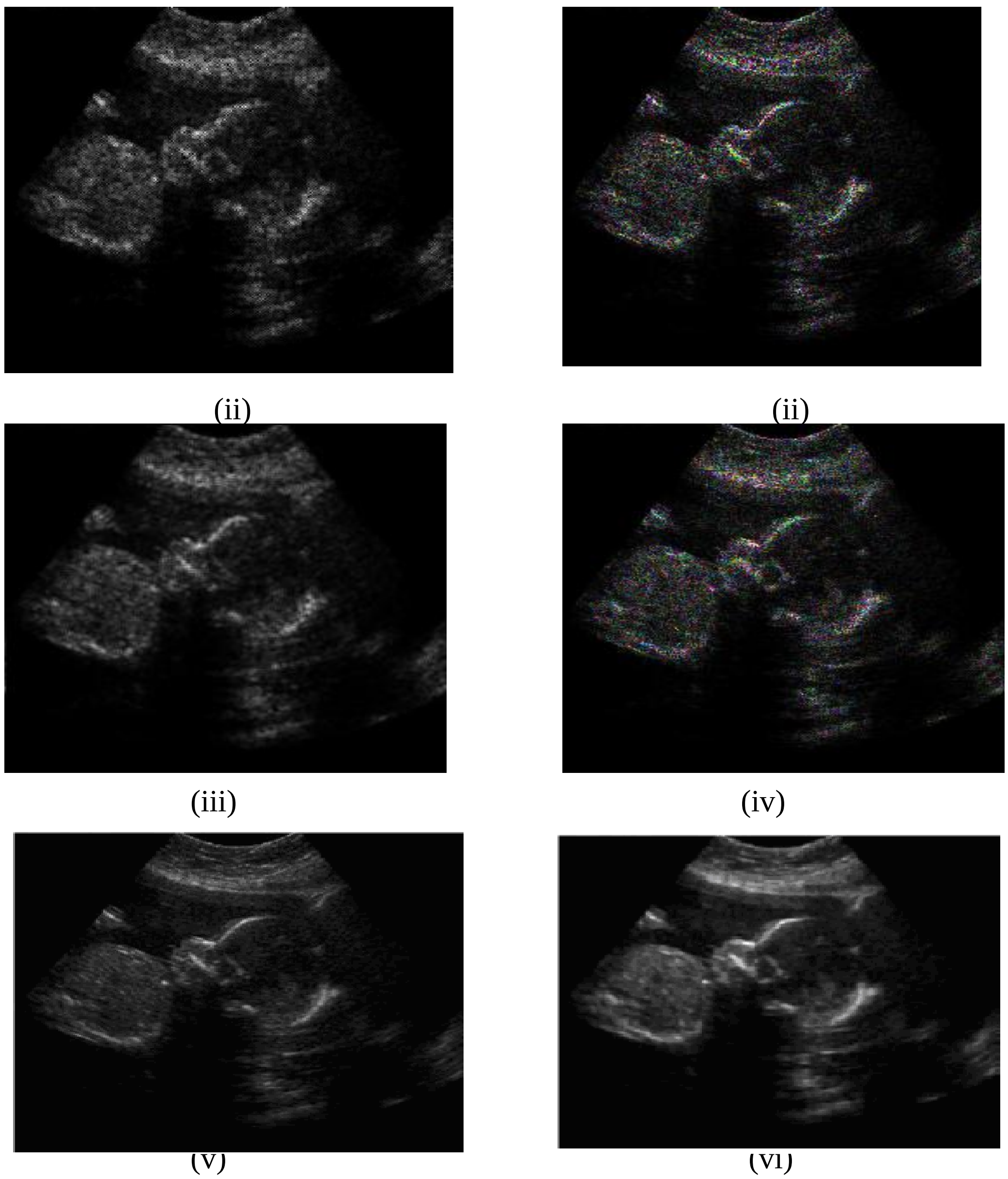


Fig 2: Denoising of 'Ultrasound' image corrupted by Speckle Noise of Variance of 0.04.

(i) Noisy image, (ii) Kaun filter, (iii) Frost filter, (iv) Weiner filter (v) Bayes threshold (vi) Proposed method

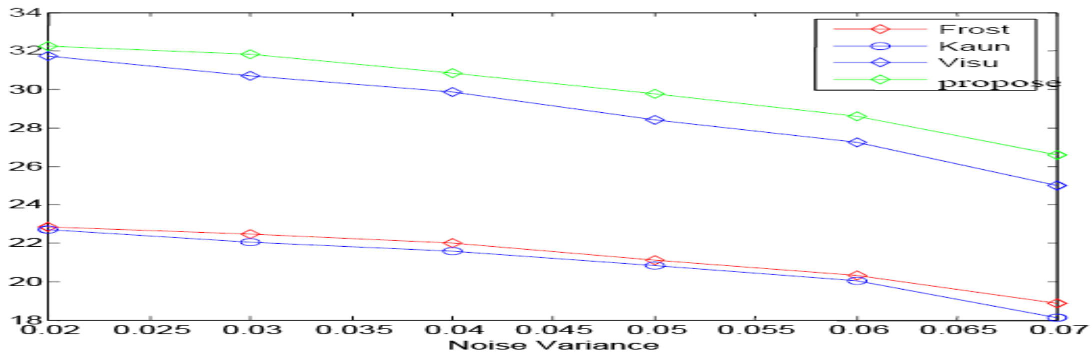
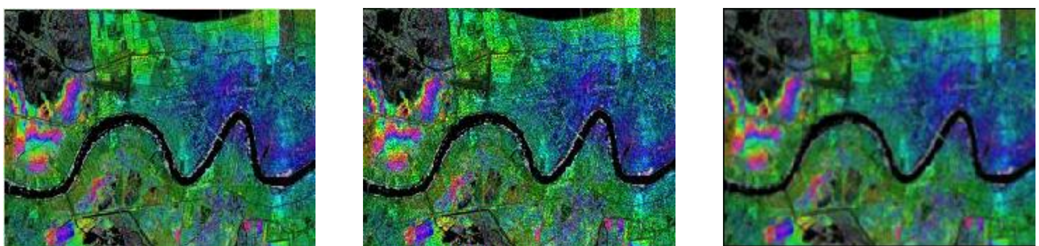


Fig.3: Comparison Chart of PSNR of different denoising methods for 'Ultrasound' Image



(a) (b) (c)

Fig.4: a) Original SAR Image
b) Degraded SAR Image by Speckle noise with variance 0.04
c) Denoised SAR Image.

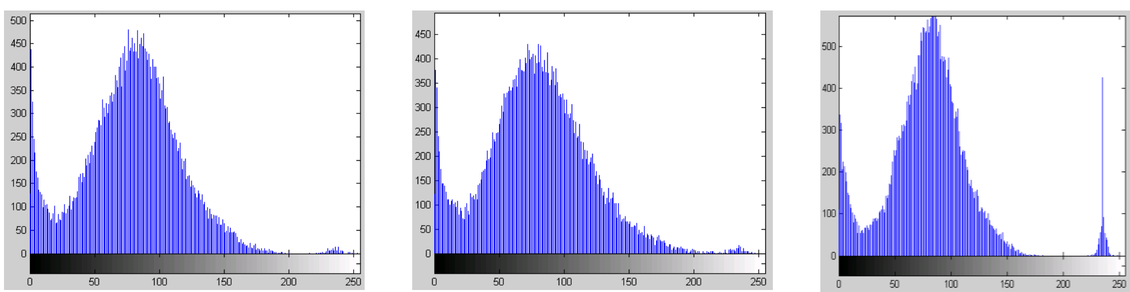


Fig 5: Histogram of a) Original SAR Image
b) Degraded SAR Image by Speckle noise with variance 0.04 c) Denoised SAR Image.

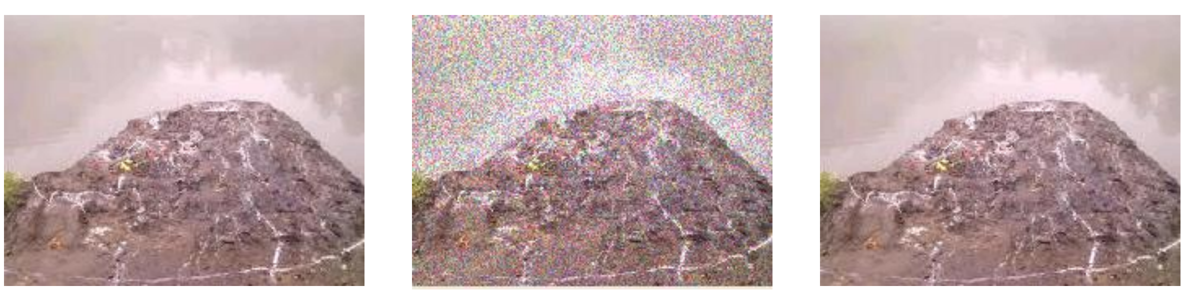


Fig. 6 a) Original SAR Image b) Degraded SAR Image by Speckle noise with variance 0.04
c) Denoised SAR Image

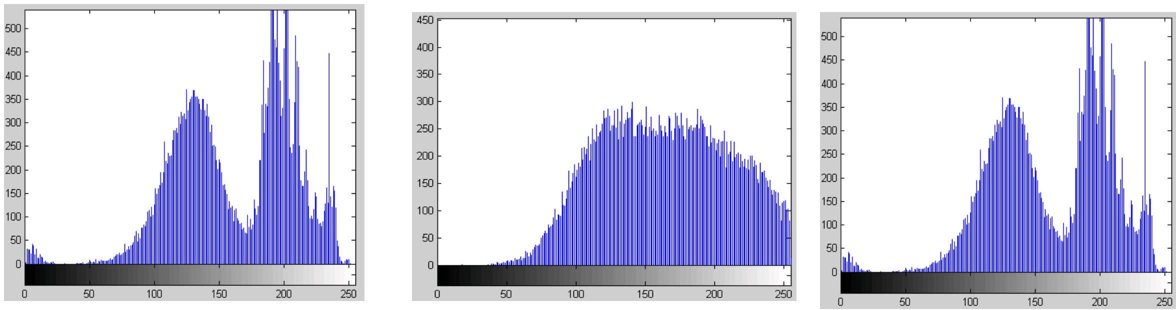


Fig. 7: Histogram of a) Original SAR Image
b) Degraded SAR Image by Speckle noise with variance 0.04 c) Denoised SAR Image.

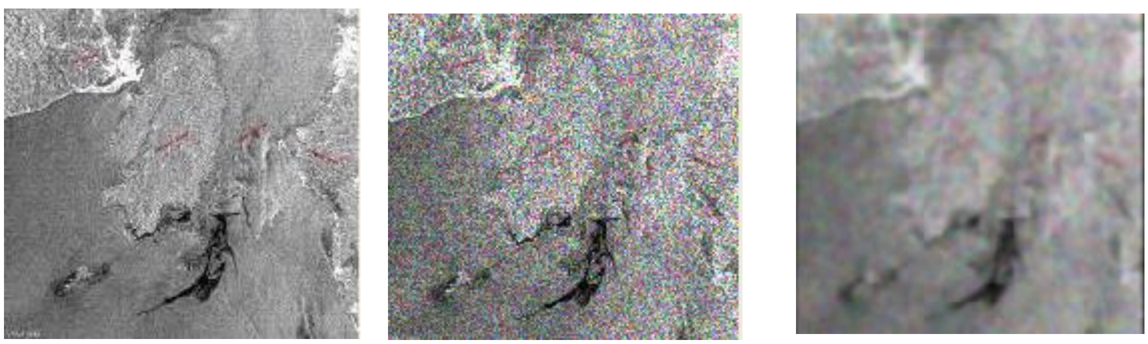


Fig. 8: a) Original SAR Image
b) Degraded SAR Image by Speckle noise with variance 0.07
c) Denoised SAR Image

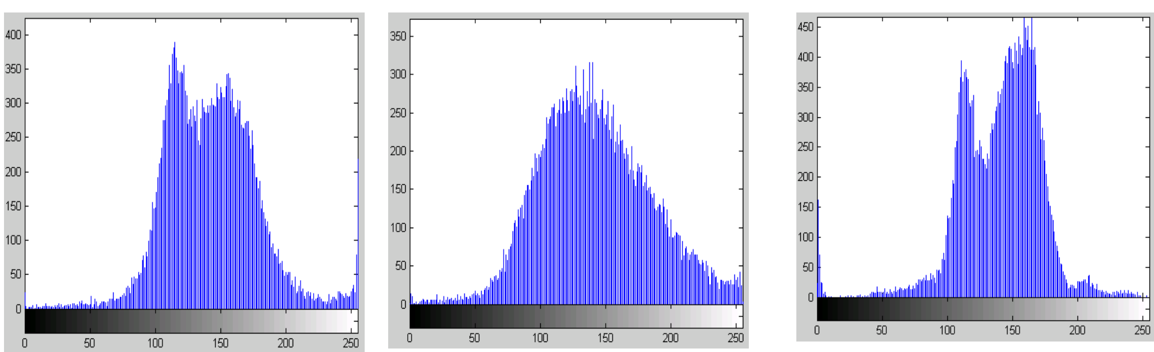


Fig.9: Histogram of a) Original SAR Image
b) Degraded SAR Image by Speckle noise with variance 0.07 c) Denoised SAR Image

5. Conclusion

We introduced a Speckle noise reduction model for Ultrasound Sound images as well as Synthetic Aperture Radar (SAR) imagery. Both models preserve the appearances of structured regions. In case of Ultrasound Images, Texture and organ surfaces have been enhanced. The performance of the algorithm has been tested using visual performance measures. Many of the methods are failure to remove speckle noise present in the Ultrasound images, since the information about the variance of the noise may not be able to identify by the methods. Introduced model automatically collect the information about the noise variance. Performance of the Speckle noise reduction model for Synthetic Aperture Radar (SAR) imagery is well as compared to other filters. Histogram results shows very closed equivalency in between SAR original images and SAR denoised i.e. enhanced images.

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