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Speckle Noise Removal and Enhancement of SAR Images

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***Abstract-** Synthetic Aperture Radar (SAR) images are mostly corrupted by speckle noise and this type of noiseisproduced due to the coherent nature of scattering phenomenon, so the removal of speckle noise from the SAR images without the loss of structural features and textural information becomes very necessary. This paper presents the de-noising of SAR image and enhancement techniques for providing good visual quality to the SAR images. Here the wavelet thresholding technique is applied to noisy SAR image then Contrast Enhancement Techniques and finally morphological operation is implemented on de-noised SAR image. In this paper the implementation of de-noising technique with the enhancement techniques as a whole is the proposed method. The experimental results show the proposed method outperforms. The tabulated results of all techniques are shown in terms of Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) parameters. The proposed approach provides better visualization effectiveness and improvement in both parameter values. All the simulation is done with the help of MATLAB R2010a environment.*

***Keywords-** SAR, DWT, ContrastEnhancement, Morphological Operation, PSNR, MSE.*

I. INTRODUCTION

Synthetic Aperture Radar (SAR) is a type of a sensor. Which is also called coherent microwave sensor. It has high penetration power and due to this property it acquires high resolution images in almost all atmospheric conditions but the automatic interpretation of SAR images is often difficult due to interference of speckle noise. It degrades the image quality. So the SAR image de-noising procedure is aimed to remove the noise without losing the important information and try to remain the structural features and textural information of the imageas much as possible. Normally, image de-noising is done by linear filters like spatial filter, Gaussian filter and Wiener filter but Wavelet Analysis is more efficient than all these filters[1],[2]. For making the visual impact more effective of SAR imageafter the de-noising process, the three enhancement techniques and than the morphological operaion are applied one by one.
These three techniques are Image Adjustment (IA), Histogram Equalization (HE) and Adaptive Histogram Equalization (AHE).

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In the de-noising process, the Discrete Wavelet Transform decomposes the SAR image into a form of coefficient's series. In this series, small coefficients are influenced by noise and large coefficients carry more useful information [3]. So below a certain level of a threshold value, noisy coefficients are removed and de-noised image is obtained.
Here, the DWT is used to remove speckle noise from the SAR image and at enhancement section all three techniques are applied to de-noised image then the morphological operation is applied, after this the results of AHE and morphological operation are compared with each other.
In the contrast enhancement process, first method is the Image Adjustment Technique; it is used for contrast adjustment of de-noised SAR image and brings out the details that have been obscured. Now the second is Histogram Equalization (HE) Technique that is being operated on the small areas of images. So for the entire image contrast enhancement, third Adaptive Histogram Equalization (AHE) Technique is used. Each region's contrast is enhanced so the histogram of the output region approximately matched with the specified histogram.
At Last the Morphological operation is applied which gives more information and contrast enhancement than the other three techniques. It is a mathematical operation and using two transforms these are Top-hat and Bottom-hat.
The whole paper is organized in five sections. Section I gives an introduction, section II describes the basic concept of DWT, Contrast Enhancement Techniques and Morphological Operation Mathematically. Section III contains the de-noising algorithm and proposed enhancement method, it is also narrating the block diagram for all coding schemes.

II. BASIC CONCEPT

A. Discrete wavelet transform

The discrete wavelet transform is used for decomposition of image into family of functions [4]:

$$\Psi_{j,k}(t) = 2^{\frac{j}{2}}\Psi(2^j t - k), \qquad j,k\epsilon Z \quad (1)$$

The mother wavelet is obtained from scaling function φ(t).

$$\varphi(t) = \Sigma_n h(n)\sqrt{2}\varphi(2t-n), \qquad n\epsilon Z \quad (2)$$

$$\Psi(t) = \Sigma_n h(n)\sqrt{2}\varphi(2t-n), \qquad (3)$$

Where,

$$h(n) = (-1)^n h(1-n) \qquad (4)$$

By applying 2-dimensional DWT to image, the image is divided into four subbands and these all subbands are created from low pass filter L and high pass filter H by down sampling with a factor two [5],[6].

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Then the approximation coefficient cAj is decomposed at the decomposition level j in four components, which are the approximation coefficients cAj+1 at level j+1 and rest three are the detail coefficients[7],[8].
These detail coefficients are distributed in three different orientations namely horizontal, vertical and diagonal and denoted by LH, HL, HH in figure (2) respectively. In this figure (2), A_j denotes the approximation coefficients at level j and all detail coefficients D_j in three directions. The tree structure of decomposition is shown in figure (1).
We are using the global median estimator by selecting Daubechies (db4) mother wavelet and soft thresholding scheme is taken.

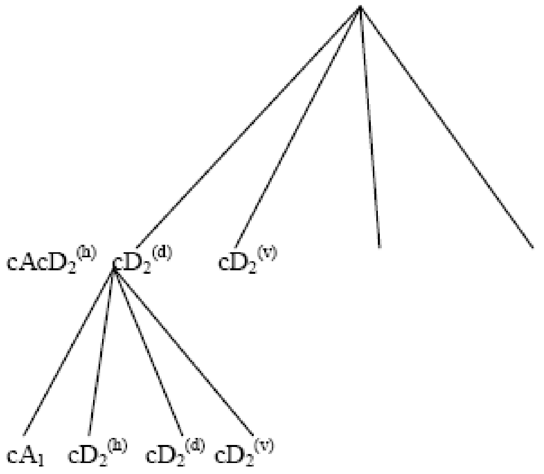

Figure 1: Tree structure of wavelet decomposition at j=2

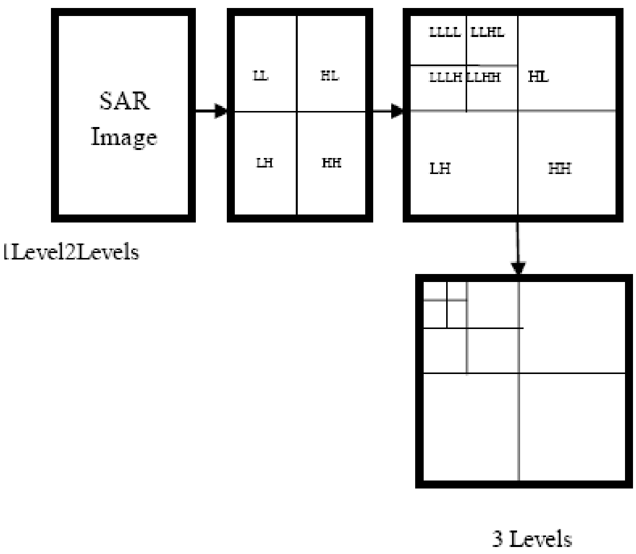

Figure 2: Three Level Image Decomposition Using DWT

B. *Contrast Enhancement Techniques-*

A visual image analysis is always rich in terms of information. Image Enhancement is very simple and interesting area among all types of digital image processing techniques. So in this paper three contrast enhancement techniques namely Image Adjustment, Histogram Equalization (HE) and Adaptive histogram Equalization (AHE) are applied to each band of de-noised SAR image because the SAR image is an RGB image so it contains three planes [9]. The main goal of these techniques is to bring out detail that is hidden in the image or to improve the contrast of the SAR image [10],[11]. So all the three techniques are applied one by one on de-noised SAR image and trying to enhance the visual quality of SAR image.

C. *Mathematical Morphology-*

The Morphological Operation is our proposed method that helps to access more improved visual quality of de-noised SAR image.

In this mathematical approach the combination of two operations is used to enhance the SAR image and these are Top-hat Transform and Bottom-hat Transform.

1. Top-hat Transform: - In Top-hat Transform, Top-hat filtering is used and in this filtering process morphological opening (F o A) is computed and subtracts the result from de-noised image (F). Where A is a structuring element (SE) [12] ,[13] and this whole process is defined as,

$$h_o = F - (FoA) \qquad (5)$$

2. Bottom-hat Transform:- In Bottom-hat Transform, Bottom-hat Filtering is used and in this filtering process morphological closing (F · A) is computed and then the de-noised image is subtracted from this closing result. This transform is defined as,

$$h_c = (F.A) - F \qquad (6)$$

These two operations described in equations (5) and (6) are performed together for the enhancement of de-noised image and then the morphological operation is defined as,

$$F_1 = F + ho - hc \qquad (7)$$

Where h_o and $h_c$is taken from the equations (5) and (6), F_1 is the morphologically enhanced image and this image is better than other enhancement techniques. So our proposed contrast enhancement method (Mathematical Morphology) is better than other enhancement techniques (Image adjustment, HE and AHE) [14],[15], which is clearly shown in the result section.

III. PROPOSED METHOD

This section describes the proposed method for efficiently de-noising and enhancing the SAR image. This method has two major steps one is de-noising and the other is enhancement respectively, this is also shown with the block diagram.This block diagram specifies that a SAR image has been taken as an input and after the two steps of processing we finally get the de-noised and enhanced SAR image.

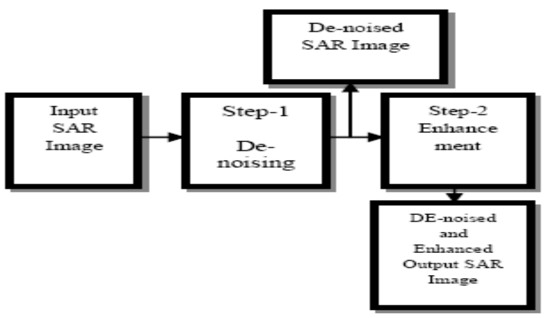

Figure 3: Block diagram of proposed method for SAR Image

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A. De-noising Algorithm-

Let suppose that the original SAR image is S and by adding the white Gaussian noise n in the original image, noisy SAR image is obtained. This noisy image is denoted by S_n, which is expressed as:

$$S_n = S + n \qquad (8)$$

For the de-noising of this noisy image, D. Donoho's method is applied and the method is explained by using the following steps:

1. Apply the Discrete Wavelet Transform (DWT) on noisy SAR image $S_n$and then the decomposition is performed with the help of db4 wavelet family uo to the level 3.
2. Now use the threshold value T by using which the coefficients will either removed or remain unchanged because coefficients below T will be zero.
3. Finally apply Inverse Discrete Wavelet Transform (IDWT) on obtained coefficients to reconstruct the SAR image.

The de-noising method uses soft thresholding and global median estimator that is taken by default threshold value for every coefficients [16]. The mother wavelet daubechies (db4) has taken. These all de-noising steps are explained below with the help of Block Diagram.

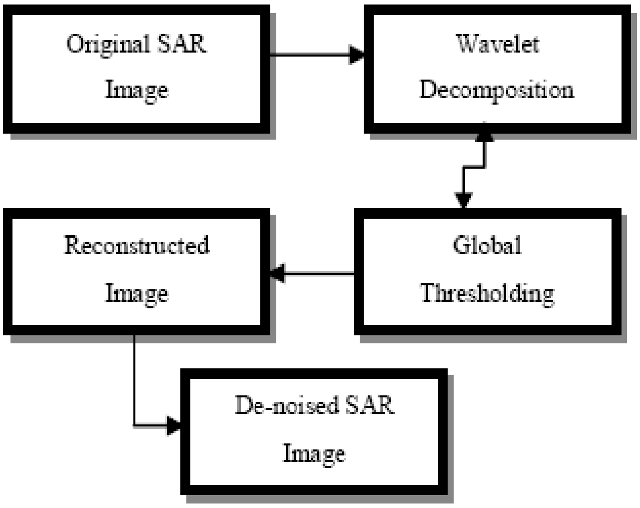


Figure 4: De-noising Block diagram of SAR Image

B. Enhancement Algorithm-

Enhancement algorithm is the combination of four contrast enhancement, explained by using simple steps and these steps are as follows,

1. First of all the Image Adjustment Technique is applied over all three planes of de-noised SAR Image and then we get adjusted SAR image.
2. Then the second technique that is Histogram Equalization (HE) Technique is implemented further on de-noised SAR image at all three planes and the result image is obtained as Histogram Equalized image.
3. Now the AHE technique is employed to the image which is output of step-1 and resulting image is adaptively equalized of histogram image.
4. Finally Morphological Operation is executed to de-noised SAR image for better improvement of contrast on SAR image.

These all four steps are also explained by using Block Diagram and this is shown in figure (4).

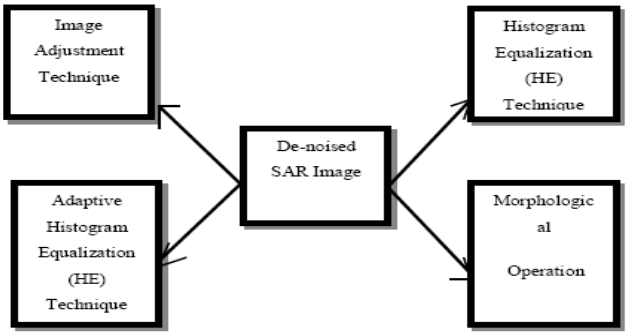


Figure 5: Enhancement Block Diagram of De-noised SAR Image

IV. RESULTS AND DISCUSSION

Thispaper proves that after de-noising and then combining enhancement techniques with the morphological operation, made convenient to the evaluationof the performance of proposed method.

A. DE-NOISING RESULTS-

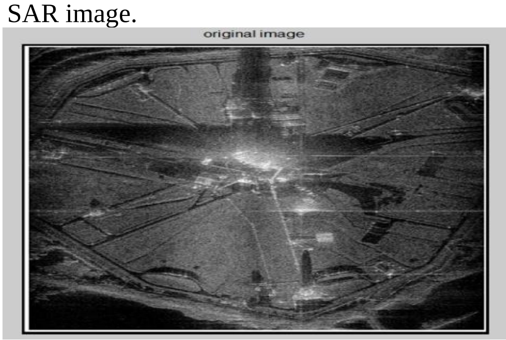
Results of de-noising procedure in this paper approves the efficiency of DWT. The experiments are carried out on three test images of SAR at different noise levels σ=0.01, 0.02, 0.03 and 0.04. The objective quality of images is measured by ISNR (Input Signal to Noise Ratio), PSNR (Peak Signal to Noise Ratio) and ESNR (Enhanced Signal to Noise Ratio):

$$PSNR = 10log\frac{(255)^2}{MSE}dB \qquad (9)$$

All other ratios are also evaluated by using the above formula by changing the input image. Higher the value of ratios show the better de-noising and enhancement method accordingly. Where, MSE is mean square error between original and de-noised SAR image:

$$MSE = \frac{\sum_{M,N}[I_1 - I_2]^2}{M * N} \qquad (10)$$

In equation (10) M and N are defining the number of rows and columns in the original SAR image respectively. All Ratios and MSE give different values for all three tested SAR images on different – different noise variance in Table I and II respectively. In figure (5) the de-noising results are shown, figure 5 (a) is an original SAR image, 5 (b) is a white Gaussian noisy image with 0.04 noise variance and this image is to be de-noised further 5 (c) shows the de-noised SAR image.



5 (a) :Original Image

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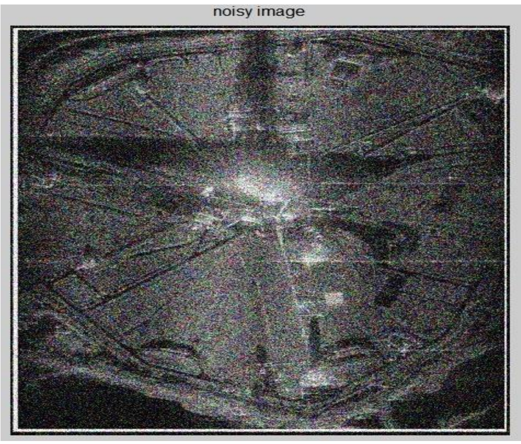
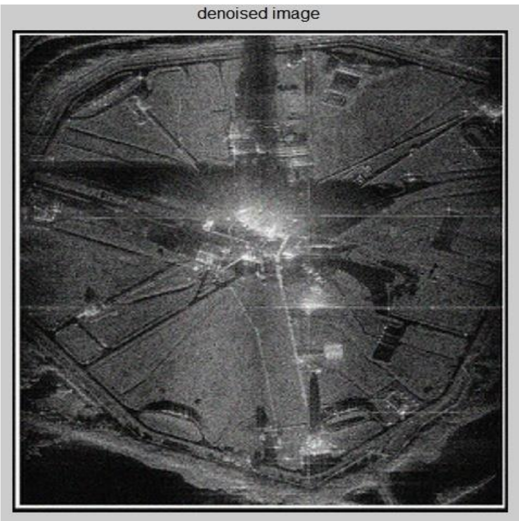


5 (b):Noisy Image (σ=0.04)



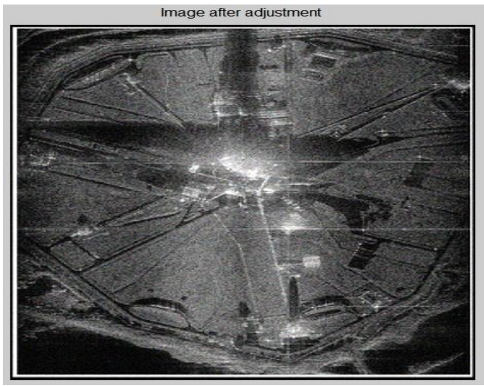
5 (c):De-noised Image

Figure 5: Results of De-noised method on SAR image

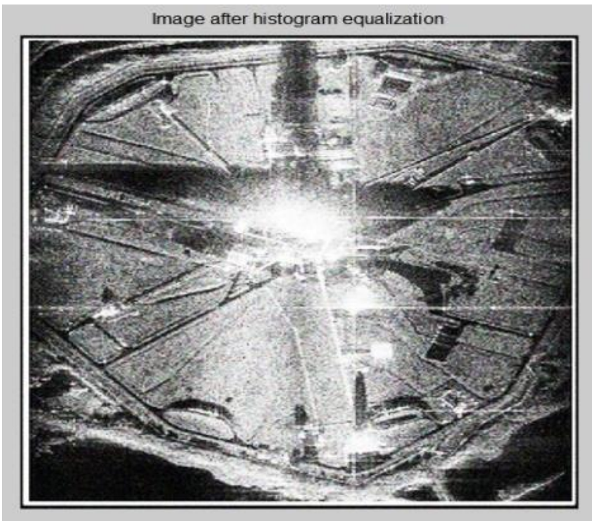
B. ENHANCEMENT RESULTS-

The images are ever analyzed and perceived according to the visual quality of them so here for enhancing the perception quality of SAR image contrast enhancement techniques are applied and got the expected results.According to the proposed method the enhancement techniques are applied and the results are executed in the figure 6 respectively.

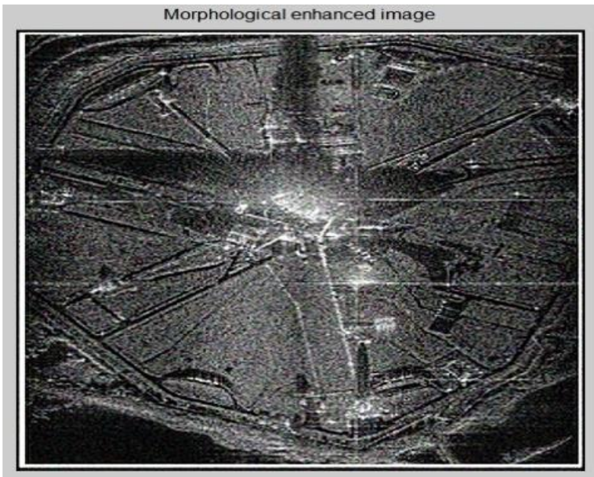
Figure 6 (a) showing the result of contrast adjustment after it 6 (b) image of histogram equalization technique is shown, figure 6 (c) is adaptively equalized histogram image and then 6 (d) is the image after applying the morphological operation.



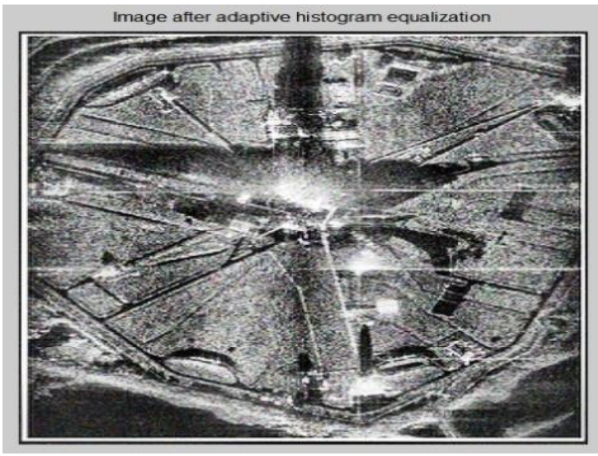
6 (a):Image after Adjustment



6 (b):Image after Histogram Equalization(HE)



6 (c) :Image after Adaptive Histogram Equalization(AHE)



6 (d):Final result after Morphological EnhancemenFigure 6 Result of proposed method on SAR Image

The tables of PSNR and MSE showing the reliability of the results. In table 1 the different kind of signal to noise ratios are tabulated at different noise variance and in table 2 MSE is defined for before de-noising, after de-noising and after morphological enhancement.

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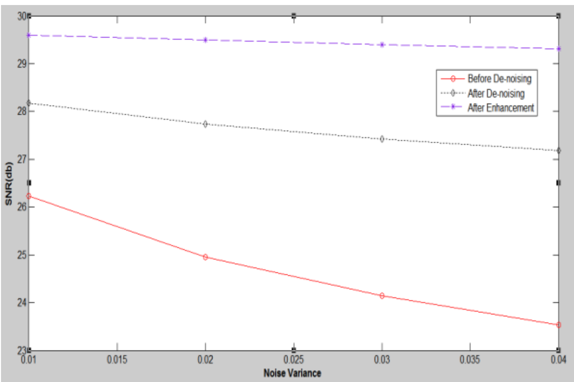
Table I: Signal to Noise Ratio on different Noise Variances

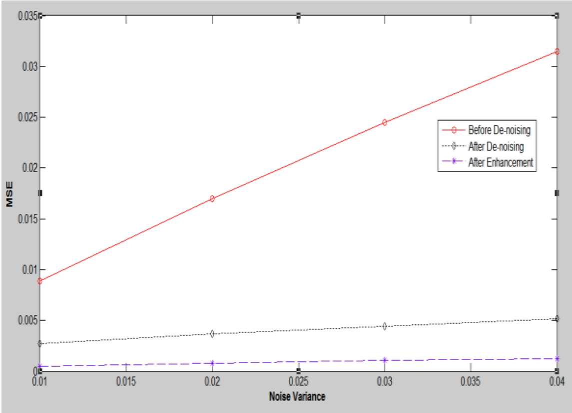
Noise Variance				
σ	0.01	0.02	0.03	0.04
SAR Image 1				
ISNR(dB)	26.2329	24.9546	24.1433	23.5338
PSNR(dB)	28.1731	24.5127	27.4282	27.1776
ESNR(dB)	29.6003	29.4948	29.3998	29.3162
SAR Image 2				
ISNR(dB)	26.3658	25.1051	24.2910	23.6839
PSNR(dB)	25.9382	25.6990	25.5275	25.3821
ESNR(dB)	29.0996	29.1168	28.9911	28.8972
SAR Image 3				
ISNR(dB)	26.0971	24.8240	23.9732	23.3524
PSNR(dB)	27.4948	27.2437	27.0682	26.8947
ESNR(dB)	26.7675	26.7467	26.7573	26.6866

Table II: Mean Square Error on different Noise Variances

Noise Variance				
σ	0.01	0.02	0.03	0.04
MSE-SAR Image 1				
Before De-noising	0.0089	0.0170	0.0245	0.0315
After De-noising	0.0027	0.0037	0.0044	0.0052
After Enhancement	0.0005	0.0008	0.0011	0.0012
MSE-SAR Image 2				
Before De-noising	0.0083	0.0159	0.0230	0.0296
After De-noising	0.0104	0.0118	0.0129	0.0139
After Enhancement	0.0014	0.0014	0.0015	0.0016
MSE-SAR Image 3				
Before De-noising	0.0096	0.0181	0.0263	0.0338
After De-noising	0.0043	0.0050	0.0055	0.0061
After Enhancement	0.0066	0.0067	0.0067	0.0069



Plot1:Comparative Performance of Proposed Method between SNR vs Noise Variance



Plot 2: Comparative Performance of Proposed Method between MSE vs Noise Variance

The plots are supporting the values and performance of DWT and the enhancement technique which is best among the four. As expected the PSNR values are increasing and the MSE values are decreasing which can be easily seen in the plots. Plot 1 is in between the SNR and noise variances and Plot 2 is between MSE and noise variances.

V. CONCLUSION

Results are giving the viability of the proposed method, the two major steps in this proposed method making the results more precise. De-noising process shows that DWT is performing superior and according to enhancement results this paper concludes that morphological operation is giving the best results with compare to other three techniques. So overall the proposd method described in this paper specially highlighting the competence of DWT and morphological operation.

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