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Speckle Noise Suppression of SAR Color Image using Hybrid Mean Median Filter

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ABSTRACT
Synthetic Aperture Rader (SAR) color images are inherently affected by multiplicative speckle noise, which is a granular noise that degrades the quality of SAR information content. Image interpretation, recognition and terrain classification processes become very difficult due to the presence of speckle noise. In this paper, an algorithm using Hybrid order statistics filter- HMM (Hybrid Mean Median) is proposed, which is a combination of mean and median filters to suppress speckle noise in SAR color images. The filter is tested with color SAR color image by two different mask sizes of 7*7 and 5*5. The performance of the proposed filter is tested against the standard filters such as Frost, Kuan, Lee and Median for reduction of speckle noise. The performance metrics shows that the proposed filter performs better in terms of PSNR and MSE.

General Terms
Image Processing, Image Denoising.

Keywords
Despeckling, Detail preservation, FIR substructures, Order Statistics Filter, SAR color images, Speckle noise.

1. INTRODUCTION
Synthetic Aperture Radar (SAR) is an active remote sensing system, which is used to obtain high resolution images. Information is collected by transmitting the signal and measuring the scattered or reflected energy back from the target material and operates at all weather conditions. Unlike optical images, SAR system illuminates a terrain with micro- waves and records both the amplitude and the phase of the back-scattered radiation, making it a coherent imaging process. The wave reflected from the target material consists of contributions from many independent scattering points. The interference of these dephased but coherent waves results in the granular pattern of noise known as 'speckle'. To reduce the fluctuation and intensity of a pixel, various independent intensity values of the same pixel are averaged, which is called incoherent averaging.

Usually, SAR images are grey scale images but now-a-days due to the advancement in the technology, the SAR color images are available and also color images are more attractive than grey scale images. As in the case of grey scale images, multiplicative speckle noise is present in the color images also. Information content of the SAR color images can be perceptually enhanced with color by exploiting variations in chromaticity as well as luminance. SAR color images increase the visual appeal of the images and can be effectively analyzed because color is used to enhance the deductibility of the details within the image.

Increasing the power of the signal will increase the speckle noise by the same amount. For this reason speckle is considered as a multiplicative noise. Incoherent averaging reduces speckle at the expense of resolution. For the past two decades, several speckle reduction techniques have been developed for removing speckle and retaining edge details. However, it is still an unresolved problem and in most of the speckle reduction techniques studied by the researchers there is no comprehensive method that takes all the constraints into consideration. The speckle noise is suppressed by applying a speckle removal filters on the digital image before display and further analysis.

The paper is organized as follows: Section 2 describes the mathematical model of speckle noise. Section 3 presents the review of the adaptive speckle filters. Section 4 introduces proposed filtering technique which is the method used for reducing the speckle noise from SAR color images. Section 5 presents quality evaluation metrics used for evaluating the quality of speckle reduction technique. In section 6, presents the experimental results on SAR color images and the conclusion is given in section 7.

2. MATHEMATICAL MODEL OF SPECKLE NOISE
In practice, a digital image generated from the SAR echo returns is represented by spatial variations of pixel intensities over the area. The speckle noise model may be approximated as multiplicative and is given by

$$D_{m,n} = S_{m,n} * U_{m,n} + V_{m,n} \quad (1)$$

Where $D_{m,n}$ is the noisy pixel, $S_{m,n}$ represents the noise free pixel, $U_{m,n}$ and $V_{m,n}$ represent the multiplicative and additive noise respectively and m,n are indices of the spatial locations. Since the effect of additive noise is considerably smaller when compared to that of multiplicative noise, (1) may be written as

$$D_{m,n} \approx S_{m,n} \quad (2)$$

Logarithmic compression is applied to the noisy signal which affects the speckle noise statistics and it becomes very close to white Gaussian noise. The logarithmic compression transforms multiplicative form in (2) to additive noise form as

$$\log(D_{m,n}) = \log(S_{m,n}) + \log U_{m,n} \quad (3a)$$

$$G(m,n) = R(m,n) + N(m,n) \quad (3b)$$

The term $\log(D_{m,n})$, which is the SAR image after logarithmic compression is denoted as G(m,n), and the terms $\log(S_{m,n})$ and $\log(U_{m,n})$,which are the noise free pixel and noisy components are denoted as R(m,n) and N(m,n) respectively after logarithmic compression. This model formulates the speckle as a multiplicative modulation of the scene reflectivity. Hence, the speckle effects are more pronounced in a high intensity area than in a low intensity area.

A commonly used filter is the Lee filter. It is based on local variance statistics, but research in this area is still open. The primary goal of speckle reduction is to remove the speckle without losing the fine details contained in an image. To achieve this goal, FIR Median Hybrid filters with different substructures are combined with the Multilevel Order Statistics Filters to get better results for terrain classification, target detection and other applications.

A well understood image enhancement method is Linear filtering, which gives good noise attenuation but smears the edges and attenuates narrow lines. The performance of linear filtering can be enhanced by optimizing the filter using noise and signal statistics. Another interesting major class of image enhancement algorithms is based on ranked order statistics. The best known of these is the median filter, and in a noise free situation the impulse response of this median filter is zero and the step response is the step signal. On flat regions of the image, median filters attenuate noise in a very similar manner to linear low-pass filters. However, in the neighborhood of edges the output of the filter becomes more and more prone to large changes in the direction of the edge as the filter slides over the edge.

Nieminen et al. reported a new class of nonlinear filters called FIR Median Hybrid filters (FMH filters) for image processing. These filters reduce the number of data sorting operations to a small constant irrespective of the window size and require only simple averaging operations. Multilevel median operations make it possible to build both FMH and median filters that retains details of the image. By increasing the number of levels in the tree, the filter becomes less sensitive to detail orientations.

3. REVIEW OF THE ADAPTIVE SPECKLE FILTERS

Adaptive filters modify the images based on statistics that are extracted from the local environment of each pixel. These filters reduce speckle noise while preserving the edges.

3.1 Lee Filter

The Lee filter [1] is based on the approach that if the variance over an area is low or constant, then the smoothing will be performed. Otherwise, if the variance is high, smoothing will not be performed. The equivalent number of looks (ENL) is a parameter used to estimate noise variance and it effectively controls the amount of smoothing applied to the image by the filter. A smaller ENL value leads to more smoothing; a larger ENL value preserves more image features. In order to filter pixels located near the edges of the image, edge-pixel values are replicated. Since speckle noise in SAR color images is generally assumed to be a multiplicative error model, in the Lee filter [2], the multiplicative model is first approximated by a linear model. Then the minimum mean square error criterion is applied to the linear model. The resulting grey level value R for the smoothed pixel is:

$$R(m,n) = I_c(m,n) * w + \overline{G} * (1 - w) \quad (4)$$

where

$$w = 1 - C_u\,\hat{}2 / C_i\,\hat{}2 \quad (5)$$

$$C_u = \sqrt{(1/ENL)} \quad (6)$$

$$C_i = S/\bar{G} \quad (7)$$

I_c= center pixel of filter window

$\overline{G}$ = mean value of intensity within window

S = standard deviation of intensity within window

C_u is the estimated noise variation coefficient, Ci is the image variation coefficient and W is a weighting function.The main disadvantage of Lee filter is that it tends to ignore speckle noise in the areas closest to edges and lines.

3.2 Kuan Filter

The Kuan filter [3] is used primarily to filter speckled radar data. It is designed to smooth out noise while retaining edges or shape features in the image. The filter size can be specified through the filter size parameters. Different filter sizes will greatly affect the quality of processed images. If the filter is too small, the noise filtering algorithm is not effective. If the filter is too large, subtle details of the image will be lost in the filtering process. A 7x7 filter usually gives the best results. Kuan filter performs spatial filtering on each individual pixel in an image using the grey level values in a square window surrounding each pixel. Kuan filter first transforms the multiplicative noise model into a signal-dependent additive noise model. Then the minimum mean square error criterion is applied to the model. The resulting filter has the same form as the Lee filter but with a different weighting function. The resulting grey-level value R for the smoothed pixel is:

$$R(m,n) = I_c(m,n) * w + \bar{G} * (1-w) \quad (8)$$

where

$$w = ((1 - C_u{}^2)/C_i{}^2)/(1 + C_u{}^2) \quad (9)$$

$$C_u = \sqrt{(1/ENL)} \quad (10)$$

$$C_i = S/\bar{G} \quad (11)$$

Ic = center pixel in filter window
$\bar{G}$ = mean value of intensity within window
S = standard deviation of intensity within window
C_u is the estimated noise variation coefficient, C_i is the image variation coefficient and W is a weighting function.

The Kuan filter made no approximation to the original model, so it can be considered to be superior to the Lee filter. The Kuan filter can be directly derived by applying the MMSE criterion to the multiplicative model. The only limitation with this filter is that ENL parameter is needed for computation.

3.3 Frost Filter

Frost filter [4] uses an adaptive filtering algorithm which is an exponentially damped convolution kernel that adapts itself to features by using local statistics. The Frost filter differs from the Lee and Kuan filters by the fact that the image reflectivity is estimated by convolving the observed image with the impulse response of the SAR system. The impulse response of the SAR system is obtained by minimizing the mean square error between the observed image and the image reflectivity model, which is assumed to be an autoregressive process. The MASK parameter specifies the area within the input channel which will be processed. Only the area under the mask is filtered, and the rest of the image is unchanged. The implementation of this filter consists of defining a circularly symmetric filter with a set of weighting values W for each pixel:

$$w(m,n) = \exp(-A * T) \quad (12)$$

where

$$A = DAMP * (\frac{v}{I} ** 2) \quad (13)$$

T is the absolute value of the pixel distance from the centre pixel to its neighbours in the filter window, DAMP is the exponential damping factor, V is the variance of the grey-level in the filter window and I**2 is the square of the mean grey level in the filter window. The resulting grey-level value R for the smoothed pixel is:

$$R(m,n) = (P_1 * M_1 + P_2 * M_2 + \cdots + P_n * M_n)/(M_1 + M_2 + \cdots + M_n) \quad (14)$$

where $P_1, .., P_n$ are grey levels of each pixel in filter window and $M_1, .., M_n$ are weights for each pixel. These weighting factors decrease as the variance within the filter windows reduces.

3.4 Enhanced Frost Filter

The Enhanced frost filter [13]is an extension of the Frost filter that further divides the radar image into homogeneous, heterogeneous and isolated point target areas. It applies a different exponentially weighting factors M in eqn (8) to optimally filter each region.

$$w(m,n) = \exp(-A * T) \quad (15)$$

Where

$$A = DAMP * (C_i - C_u)/(C_{max} - C_i) \quad (16)$$

C_i is the local coefficient of variation of the filter window.

$$C_i = S/I_m \quad (17)$$

C_u is the speckle coefficient of variation of the image using equivalent number of looks.

$$C_u = 1/\sqrt{ENL} \quad (18)$$

C_{max} is the upper speckle coefficient of variation of the image.

$$C_{max} = \sqrt{(1 + 2/ENL)} \quad (19)$$

If C_i is less than C_u, the speckle is removed by replacing the value of the filtered pixel with the intensity mean I_m of the filter window. This represents the homogeneous or uniform class. In the second class, if C_i falls between the lower and upper speckle coefficient of variation, the value of the filtered pixel is replaced by the total weighted value in eqn (12).

$$R(m,n) = (P_1 * M_1 + P_2 * M_2 + \cdots + P_n * M_n)/(M_1 + M_2 + \cdots + M_n) \quad (20)$$

This represents the heterogeneous class where the speckle is reduced but not removed so as to preserve the quality of the image. In the last class, C_i is larger than the upper threshold C_{max}. In this case, the value for the filtered pixel is replaced by the center pixel within the filter window. This is due to the consideration that isolated points with high reflectivity should be kept for analysis. The Enhanced Frost filter in comparison to the Frost filtering preserves the edges and texture of an image better.

3.5 Gamma MAP Filter

The focus of the Gamma or Maximum A Posteriori (MAP) filter [13, 14] is to minimize the loss of texture information by assuming that the image of forested areas, agricultural lands, and oceans are gamma-distributed scenes. This approach is better than the Frost and Lee filter and it uses the coefficient of variation and contrast ratios whose theoretical probability density functions will determine the smoothing process. The algorithm is similar to the Enhanced Frost filter except that if the local coefficient of variation C_i falls between the two thresholds C_u and C_{max}, the filtered pixel value is based on the Gamma estimation of the contrast ratios within the appropriate filter window given in eqn (13).

$$Img(i,j) = ((w - ENL - 1) * I_m + D)/(2 * w) \quad (21)$$

where W is a weighting function.

$$w = (1 + C_u^2)/(C_i^2 - C_u^2) \quad (22)$$

and D is given as

$$D = I_m * I_m * (w - ENL - 1) * (w - ENL - 1) + 4 * w * ENL * I_m * C_p \quad (23)$$

C_i is the local coefficient of variation of the filter window.

$$C_i = S/I_m \quad (24)$$

C_u is the speckle coefficient of variation of the image using equivalent number of looks.

$$C_u = 1/\sqrt{ENL} \quad (25)$$

C_{max} is the upper speckle coefficient of variation of the image.

$$C_{max} = \sqrt{2 * C_u} \quad (26)$$

If C_i is smaller than C_u, the value of the filtered pixel will be replaced by the mean of the filter window. If C_i is greater than C_{max}, the value of the filtered pixel will be replaced by the center pixel in the filtered window. Most of these proposed local adaptive speckle filters are able to reduce speckle while preserving the SAR data. However, removal of speckle without losing any data is not possible at the moment. This is because all of these filters rely on local statistical data related to the filtered pixel. This data depends on the occurrence of the filter window over an area. The achievement of both speckle reduction and preservation of edge data is only possible when the filter window happens to cover an area that is uniform. If the filter window happens to cover an edge, the value of the filtered pixel will be replaced by the statistical data from both sides of the edge that is from two different intensity distributions. An alternative approach is to use wavelet transform. In wavelet transforms, the window size is variable depending on the contents of the image.

3.4 Mean Filter

Mean filtering [5] is a simple, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. It is often used to reduce speckle noise in SAR color images. The idea of mean filtering is simply to replace each pixel value in an image with the mean value of its neighbours, including itself. Mean filtering is usually thought of as a convolution filter. Like other convolutions, it is based around a kernel, which represents the shape and size of the neighbourhood to be sampled when calculating the mean. Often, a 3×3 square kernel is used, although larger kernels (e.g. 5×5 squares) can be used for more intense smoothing.

3.5 Median Filter

Order-statistics filters [6], [7] are nonlinear spatial filters whose response is based on ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result. Median filter is used in the SAR Filters & Textures program. Sometimes, to get better image quality, it may be useful to filter the same image two or three times. The main disadvantage of the Median filter is the extra computation time needed to sort the intensity value of each set.

3.6 FIR Hybrid-Median filter (FHM filter)

Although median filters preserve edges in digital images, they remove fine image details such as lines. In many applications such as remote sensing and X-ray imaging, this is exceedingly important and efforts have been made to develop filters that overcome the problem.

This new class of 'detail preserving' filters [10] employs linear masks whose outputs are combined by median operations. There are a great variety of such filters that employ different masks shapes and have the possibility of several layers of median operations. Although these filters are aimed particularly at retention of line detail, they turn out to have some corner preserving properties and are resistant to the edge shifts that arise when there is a nonzero curvature.

Perhaps the best of the filters in the FHM filters, from the point of view of preserving edge position, is the two-level 'bi-directional' linear-median hybrid filter. It employs the mask A to I in the 5x5 region [11] as shown in Fig.1

Pixels are marked as being in the same mask having their intensities averaged and dashed pixels being ignored. Nonlinear filtering then proceeds using two levels of median filtering, with the final centre-pixel intensity being taken as:

-	M	L	K	-
M	-	L	-	K
N	N	A	J	J
O	-	P	-	Q
-	O	P	Q	-

Fig 1. 5x5 mask for FIR Hybrid-Median Filter

$$R(m,n) = med(A, med(A,J,L,N,P), med(A,K,M,O,Q)) \quad (19)$$

This filter always gives at least a fourfold improvement in edge shift over that of the median filter. Hence, such detail-preserving filters improve the situation dramatically but do not completely overcome the problem.

4. PROPOSED FILTERING TECHNIQUE

4.1 Hybrid Mean-Median filter (HMM filter)

Hybrid Mean-Median filter is proposed with hybridization of FIR median hybrid filter and M3 filter. This filter replaces the central pixel by the maximum value of FIR hybrid median and mean for each mask of 7x7 and 5x5 as shown in Fig (2) and fig (3).

$$R(m,n) = \max(FIR\ Hybrid\ median(m,n), mean(m,n)) \quad (20)$$

where

$$FIR\ Hybrid\ median(m,n) = med(A, med(A,J,L,N,P), med(A,K,M,O,Q)) \quad (21)$$

This filter employs linear masks with the structures A , J to Q in the 7x7 and 5x5 region as in figure 2 and 3

-	-	M	L	K	-	-
-	M	-	L	-	K	-
M	-	-	L	-	-	K
N	N	N	A	J	J	J
O	-	-	P	-	-	Q
-	O	-	P	-	Q	-
-	-	O	P	Q	-	-

Fig 2. 7x7 Mask for Proposed Technique

M	-	L	-	K
-	M	L	K	-
N	N	A	J	J
-	O	P	Q	-
O	-	P	-	Q

Fig 3. 5x5 Mask for Proposed Technique

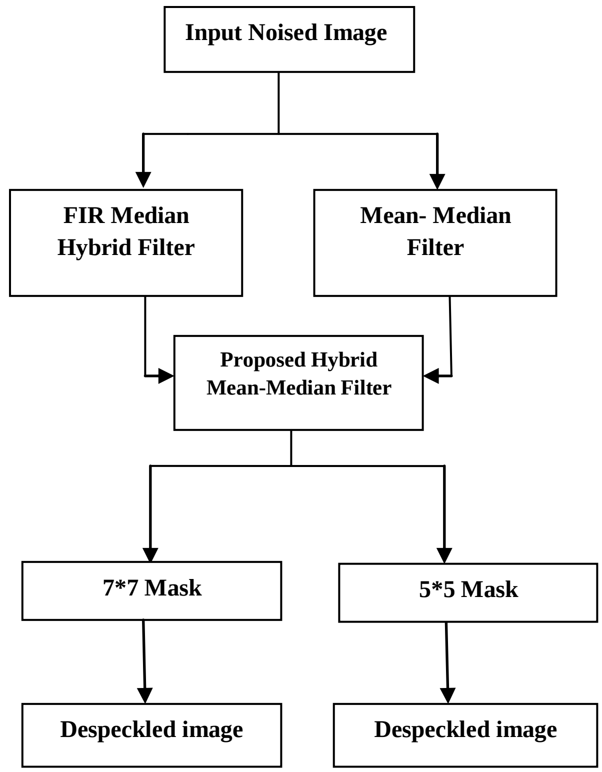

Fig 4. Flow chart for Proposed Technique

4.2 ALGORITHM

1. Divide the input SAR color image into three different Red, Green and Blue color plates.
2. For each color plate, Find the median ***MD*** of the pixels marked as ***J, L, N, P*** and the central pixel ***A*** in the 5x5 or 7x7 windows.
3. Find the median ***MB*** of the pixels marked as ***K, M, O, Q*** and the central pixel ***A*** in the 5x5 or 7x7 windows.
4. Compute ***M.***
M = *median*(***MD,MB,A***) called as FIR hybrid median filter.
5. Find the mean of all the pixels in the chosen window.
6. Filter value R(m,n) = Max(M(m,n), mean(m,n)) for individual color plates.
7. Concatenate the color plates to get output denoised image.

Hybrid multilevel median filters have preserving properties which gives at least four fold improvement in edge shift over that of the median filter. Mean and median filters are used to reduce the intensity values in the adjacent pixel and to preserve high frequency components in the image. But in Hybrid Mean-Median filter, the advantages of both FIR hybrid median and mean filter exist. The PSNR of hybrid Mean-Median filter is better than other filters because in this filter 7x7 and 5x5 masks are used as shown in the figures 2 and 3.

In SAR color images, edges are to be preserved since most of the details are present in the edges. In order to preserve the edges the vertical, horizontal, diagonal and mainly boundary pixels are considered and other pixels are ignored. Due to this reason, PSNR of hybrid Mean-Median filter is much better than all other existing filters so this may be used for reducing the speckle noise in SAR color images.

5. QUALITY EVALUATION METRICS

The proposed algorithms have been implemented using MATLAB. The measurement of image enhancement is difficult to measure. There is no common algorithm for the enhancement of the image. Statistical measurement could be used to measure enhancement of the image. The performance of each filter is evaluated quantitatively for SAR image with speckle noise using the quality metrics like Mean Square Error(MSE), Root Mean Square Error(RMSE), Peak Signal-to–Noise Ratio(PSNR), Signal-to–Noise Ratio(SNR), Equivalent Number of Looks (ENL) and Edge Save Index(ESI). Let G and R denote the original and the denoised image respectively.

5.1 Mean Square Error (MSE)

Mean Square Error (**MSE**) for two P×Q monochrome images (G and R) where one of the images is considered a noisy approximation of the other is defined as:

$$MSE = \frac{1}{PQ}\sum_{m=0}^{P-1}\sum_{n=0}^{Q-1}[G(m,n) - R(m,n)] \qquad (22)$$

5.2 Root Mean Square Error(RMSE)

The Root Mean Square Error (RMSE) is the square root of the squared error averaged over PxQ window

$$RMSE = \sqrt{\frac{1}{PQ}\sum_{m=0}^{P-1}\sum_{n=0}^{Q-1}[G(m,n) - R(m,n)^2} \qquad (23)$$

5.3 PSNR

The PSNR is most commonly used as a measure of the quality of despeckled image. The PSNR is defined as:

$$PSNR = 10\log_{10}(\frac{MAX_i^2}{MSE}) \qquad (24)$$

where MAX_i^2 is the maximum intensity in the unfiltered images. A higher PSNR would normally indicate that the reconstruction is of higher quality.

5.34SNR

Signal to Noise Ratio (SNR) compares the level of the desired signal to the level of background noise. Larger SNR values correspond to good quality image.

$$SNR = 10\log_{10}\frac{\sum_{m=1}^{P}\sum_{n=1}^{Q}(G_{m,n}^2 + R_{m,n}^2)}{\sum_{m=1}^{P}\sum_{n=1}^{Q}(G_{m,n} - R_{m,n})} \qquad (25)$$

5.5 Equivalent Number of Looks (ENL)

This index is calculated using the following

$$ENL = (\frac{mean}{SD})^2 \qquad (26)$$

where SD is standard deviation.

The higher the ENL value for a filter, the higher efficiency in smoothing speckle noise over homogeneous areas.

5.6 Speckle Suppression Index (SSI)

This index is formulated as follows:

$$SSI = \frac{\sqrt{var\,(R_{m,n})}}{mean\,(R_{m,n})}\,x\,\frac{mean\,(G_{m,n})}{\sqrt{var\,(G_{m,n})}} \qquad (27)$$

where G is the original image, *R* is the reconstructed image, m is the row number of the image, and n is the column number of the image. If the performance of the filter is efficient in suppressing the speckle noise, this index is to be less than 1.

5.6 Speckle Suppression and Mean Preservation Index(SMPI)

When the filter overestimates the mean value then ENL and SSI are not reliable. The index called Speckle Suppression and Mean Preservation Index may be used.

$$SMPI = Q * \frac{\sqrt{\boldsymbol{var}(\boldsymbol{R_{m,n}})}}{\sqrt{\boldsymbol{var}(\boldsymbol{G_{m,n}})}} \qquad (28)$$

The equation for Q is as follows:

$$Q = U + |mean(G) - mean(R)| \qquad (29)$$

Where $U = \frac{MAX\,(mean\,(R) - Min\,(mean\,(R))}{mean\,(G)}$ (30)

where G is the original image, *R* is the reconstructed image, m is the row number of the image, and n is the column number of the image.

6. EXPERIMENTAL RESULTS

6.1 Experimental Analysis and Discussion

Despeckling is carried out for SAR color image using the different standard speckle reduction filters and the Mean filter, Median filter, FIR Hybrid median filter and the proposed median filter. Simulations are carried out in MATLAB. The performances of different despeckling filters in terms of MSE, RMSE, SNR, PSNR, ENL, SSI and SMPI are compared in Table1.

The performance of the speckle filters like Lee, Kuan, Frost filters are almost the same but ENL is better for Mean filter. FIR Hybrid median filter gives better PSNR than Mean, Median and Wiener filters because boundary pixels are taken into account for preserving edges. The proposed Mean-Median filter with 7x7 mask yields good PSNR than all other filters and the Mean-Median filter with 5x5 mask produces better PSNR than other filters listed in Table. 1.

The performance metrics show that amongst the different type of speckle reduction filters listed in Table.1, the proposed Hybrid Mean-Median filter with 5x5 mask removes substantial amount of noise and also preserves edges and details. The objective measures for different filters are illustrated in Table.1.

7. CONCLUSION

Simulation results show that the proposed Hybrid Mean-Median filter with 5x5 mask yielded better SNR, PSNR and ESI_V when compared to other filters. Other performance metrics show that while removing substantial amount of noise, it also preserves edges and details.The original image and the output denoised color images of various filters are shown in figures.7-14:

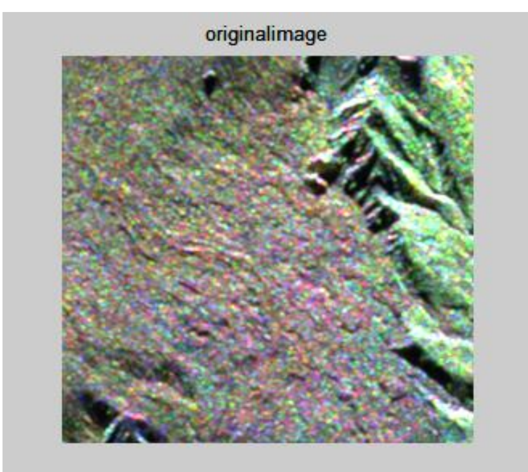

Fig 5. Original Image

TABLE.1 Performance Metrics of different filters

Para Meters	**MSE**	**RMSE**	**SNR**	**PSNR**	**ENL**	**SSI**	**SMPI**
Lee	0.0031	0.056	22.73	28.108	8.8833	0.1261	0.0013
Kuan	0.0036	0.061	22.16	27.490	8.8052	0.1267	0.0034
Frost	0.0017	0.041	25.38	30.741	8.7067	0.1274	0.0005
Mean	0.0080	0.091	18.52	23.957	**10.913**	0.1138	0.0045
Medn	0.0070	0.084	19.11	24.563	9.6777	0.1208	0.0096
Winer	0.0049	0.071	20.74	26.129	10.085	0.1184	**0.0003**
FHM	0.0028	0.055	23.21	28.611	8.6944	0.1275	0.0052
Pro7x7	0.0016	0.040	**25.78**	**30.976**	8.5015	0.1289	0.0202
Pro5x5	0.0008	0.028	**28.72**	**33.955**	7.968	0.1332	0.0130

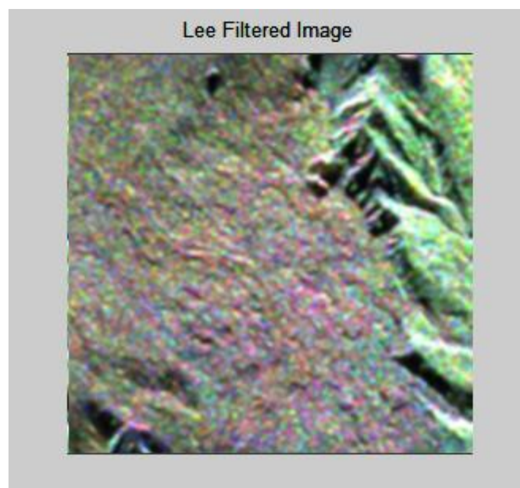

Fig 6. Despeckled Image using Lee filter

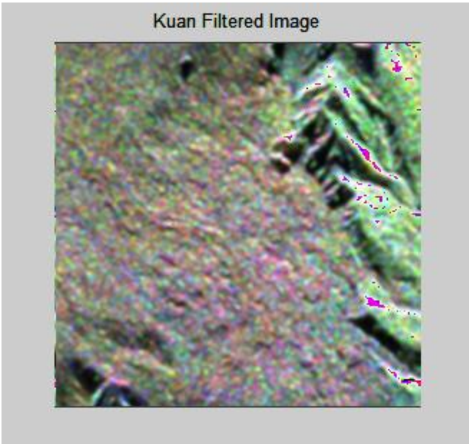

Fig 7. Despeckled Image using Kuan filter

Fig 8. Despeckled Image using Frost filter

Fig 9. Despeckled Image using Median filter

Fig 10. Despeckled Image using Mean filter

Fig 11. Despeckled Image using Wiener filter

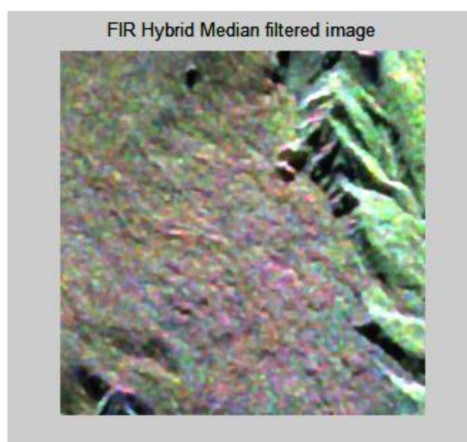

Fig 12. Despeckled Image using FIR Hybrid Median filter

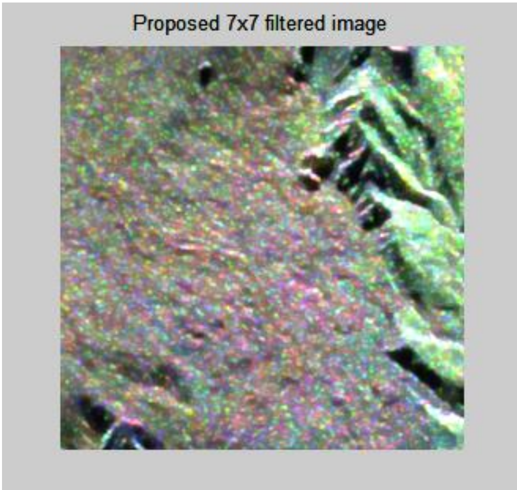

Fig 13. Despeckled Image using Proposed Hybrid Mean-Median filter with 7x7 mask

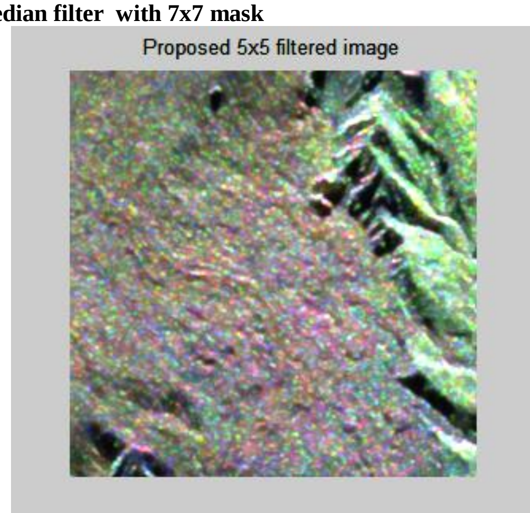

Fig 14. Despeckled Image using Proposed Hybrid Mean-Median filter with 5x5 mask

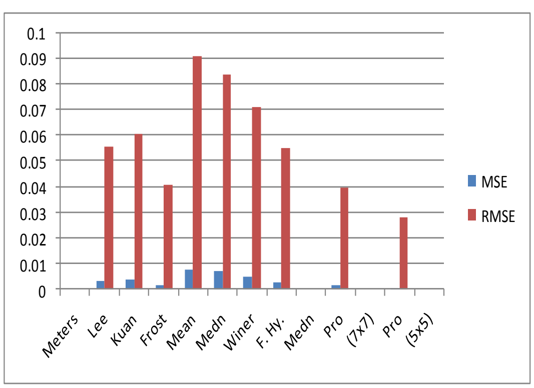

Fig.15. Filter performance in terms of MSE and RMSE

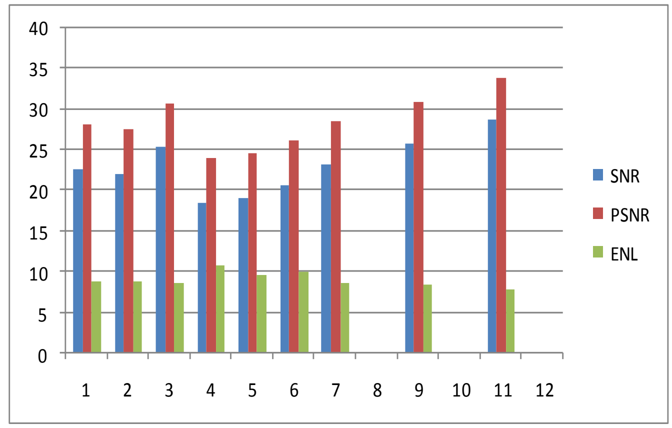

Fig.14. .Filter performance in terms of SNR, PSNR and ENL

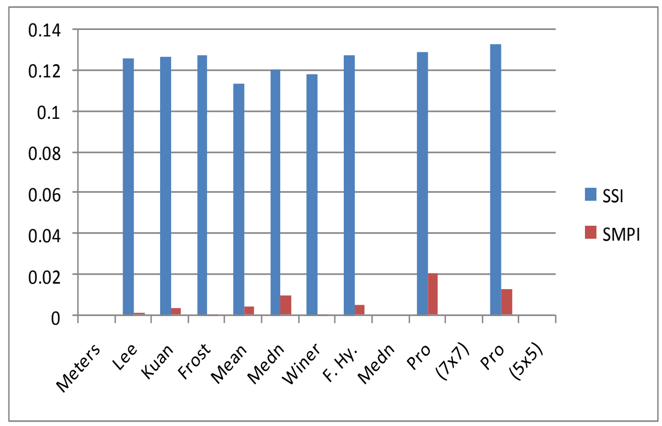

Fig.15. Filter performance in terms of SSI and SMPI

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