Design hybrid filter technique for mixed noise reduction from synthetic aperture radar imagery

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ABSTRACT

For military and civilian applications, synthetic aperture radar (SAR) imaging is an essential instrument for obtaining images of the Earth's surface. Speckle noise, a form of noise that is multiplicative, generated by conflicting echoes returned from each pixel, has a significant impact on the SAR picture. On SAR pictures, a hybrid filter for mixed noise reduction is used to remove the mixed noises that are present in the data during capture and transmission. Specifically, speckle noise and salt and pepper noises from SAR images. Both are being worked on at the same time to minimize mixed noise in SAR pictures without revealing edges or other features. This study proposes a technique that combines a hybrid filter derived from a statistics filters with nonlinear functions (SFNF). When comparing to mean, median as no adaptive filters, and frost filter, a lee filter, and fuzzy filters as adaptive filters, this hybrid filter produces good results. MATLAB was used to carry out the simulation. To illustrate the filtering technique's performance, quantitative measurements like signal to noise ratio (SNR) procedure, the mean square error (MSE) method, and edge measurement (β) mechanization are used.

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1. INTRODUCTION

Synthetic aperture radar imaging (SARI) is a key of providing pictures of the world's surface for military purposes, and it has been widely applied in a variety of disciplines, including environmental study. [1], earth's water concerning [2], terrain [3] and phonemena of the ocean [4]. Speckle noise, a form of noise that is multiplicative, created by resolving unit interference echo, has a significant impact on SARI [5], despite SAR's capacity to produce images with high degrees of resolution, images are generally attenuated by speckle noise caused by imaging equipment, which can make data interpretation difficult. As a result, even highly skilled interpreters may find it challenging to locate important sections in the pictures [6].

As a result, eliminating speckle sounds is a crucial step. This might be accomplished by filtering homogeneous regions effectively while preserving the texture and key information of the photos as much as feasible. The advent of viable tools and approaches tailored to resolving this issue has recently sparked a surge in interest in SAR picture denoising [7], [8]. Currently, it can be even collect images from the earth's many strata. SARI is the term for this type of imaging. It gets more difficult to obtain a clean and noise-free image as the distance between the lens and the object rises. There are several elements that degrade the image in various ways. Salt and pepper noise is one example of such deterioration, and the presence of white and black dots on the picture is due to this. As a result, this noise must be removed in order to produce a much clearer image [9]. Among the most major image processing is picture noise reduction [10].

Many filters have recently been developed to decrease or eliminate noise from damaged pictures, however the the bulk of them are designed to deal with a certain sort of noise but do not excute well performance in many unwanted signal environments. The classification of filters can be introduced into two types; linearty and nonlinearty. In case of single type of noise is exhibit, such as Gaussian noise, linearty filters like the mean and Wiener filter perform well. Edge information is preserved by nonlinearty filters for example order static and median, while eliminating external noise and speckle noise [11]-[13]. The methods used to reduce noise in pictures are mostly determined by the types of noise present in the image [14]. To reduce the speckle noise a nonlinear filter such as lee, kuan, frost and either are used [15].

When synthetic aperture radar SAR pictures are taken, speckle noise and salt and pepper noise are common. Distorted undesirable singal refers to the combination of Gaussian and non-Gaussian noise in the picture. In recent literature, various mixed noise reduction techniques have been reported. Research by Khriji and Gabbouj [16] a cancellation of mixed Gaussian and Impule noise has been introduce via a hybrid filter. Kwan [17] fuzzy filters are used to correct mixed noise in grayscale pictures. According tob Pitas and Venetsanopoulos [18] a median-rational hybrid filters are presented in [11], gray and color pictures with fuzzy filters are used to reduce impulsive and Gaussian noise. For speckle and poisson disturbances in dental X-ray pictures, median filtering outperformed Gaussian and finite impulse response (FIR) filtering in other research. Medical pictures are degraded by noise during transmission and procurement in this investigation. The feature values of the SAR picture are reduced when the image contrast and resolution are reduced by noise [19]. This paper will discuss the structure of the recommended hybrid filter method, which will primarily focus on Speckle noise and pepper and salt noise. To begin, it will be discuss the proposed hybrid filter approach, which combines the fuzzy classical filter with statistics filters and nonlinear filters. In addition, as compared to other filtering approaches, noise reduction may be used to enhance visual quality and image rearrangement.

2. DEGRADATION MODEL WITH MIXED NOISE

Noise is defined as any unwelcome data that tarnishes a photograph the major source of noise in digital pictures comes from the digital image capture process, which transforms image data into a continuous electrical signal that is subsequently sampled [20]. Noise and distortions removal are important difficulties in radar image processing, as well as any other sector where signals cannot be isolated from noise and distortion. Blended noise is a combination of neumerous distinctive shapes of unwelcome signals with the same distinctive implies and variation. Blended commition is produced by combining Gaussian noise with speckle noise at zero mean and different deviations, and a summation of both sounds have been added with salt and shot noise [21]. The following equation is a mathematical representation of combined varies nosie images such as noise (Gaussian and impulsive (salt and pepper)) and speckle noise.

$$F(x,y) = S(x,y) * I(x,y) + V1(x,y) + V2(x,y) \quad (1)$$

Where I (x,y) represents the pixel in the image's ith row and jth column, speckle noise S (x,y), W (x,y) is the uncorrelated process additive white noise with mean zero and variance Q (x,y),V1:- is the additive equally measured frequency noise which has a value of 0 and a variation of Q^2. The noise density of additive impulse noise V2 is D.

2.1. Categorization non-adaptive filters

2.1.1. Mean filter

It is a basic type of filter that averages the data rather than removing the speckles. In general, the least acceptable way of speckle noise reduction since it reduces resolution and detail. It can, however, be utilized for situations where resolution isn't the most important factor [22].

2.1.2. Median filter

It removes pulse or speckle noises, and also it is a simple one. Pulse functions are less than half the width step or ramp functions are retained, but the moving kernel is muted or removed [22].

2.2 Categorization of adaptive filters

2.2.1. Frost filter

It is used to replace the interest pixle with summation weighted of each pixel inside the *n*x*n* moving kernel, with reverse proportional between weighted factors and distance of each interest pixel along with proportional relation of the weighted characteristics for the center pixel and the inside dissimilarity expansion. The following formula is used to create the propose filter, which assumes multiplicative noise and stationary noise [23].

$$\bar{R}(x,y) = \sum_{i_0=x-\frac{W_{s}-1}{2}}^{x+\frac{W_{s}-1}{2}} \sum_{k_0=x-\frac{W_{s}-1}{2}}^{y-\frac{W_{s}-1}{2}} K_1 K_2 C_1^2(x,y).F(l_0,k_0)e^{-K_2 C_1^2(x,y)[|x-l_0|+|y-k_0|]} \quad (2)$$

Where, $F\ (l_0,\ k_0)$ represents the mask filter locality of pixel, K_1 means a constant standard condtion, K_2 means a damping rate controlling the constant and $C_1^2(x,y)$ means a variation coefficient.

2.2.2. Lee filter

It employes the measurable dispensation of pixel importance inside the moving kernel in order to demonstrate interest pixels utility. The propose filter uses a Gaussian dispensation to deel with the incorrect data of the image. The Lee filter elucidates that the standard deviation pixels are the same as the local mean and fluctuation of all pixels in the user-selected (moving kernel) region. The mathematical expression used for the Lee filter is [15].

$$\overline{R}(x,y) = F(x,y).W(x,y) + \overline{F}(x,y).(1 - W(x,y)) \quad (3)$$

$\overline{R}(x,y)$ exhibits undergirded picture, $F(x,y)$ described the observed image, $\overline{F}(x,y)$ demonstrate the local mean, $W(x,y)$observe the weighting function for an image model. The weighting function is given for Lee filter by [15].

$$W(x,y) = 1 - \frac{C_F^2}{C_1^2(x,y)} \quad (4)$$

Where C_F describes the variation coefficient of speckle noise, $C_1(x,y)$ refers to image variation coefficient.

2.2.3. Kuan Filter

It converts multi-model noise into an audio signal sample that is signal dependant. The model is next subjected to the lowest mean square error criteria. The resultant filter is almost identical to the Lee filter but has a variable threshold method [10].

$$W(x,y) = \frac{1-\frac{C_F^2}{C_1^2(x,y)}}{1+C_F^2} \quad (5)$$

2.2.4. Asymmetrical triangular fuzzy filter with median center

The fuzzy filter of symmetrical trapezoidal is described as an asymmetrical filter of triangle filter with the center value set as the median value inside a window:

$$R[f(x+r,y+s)] = \begin{cases} 1 - \frac{f_{med}(x,y)-f(x+r,y+s)}{f_{med}(i,j)-f_{min}(i,j)} \\ for\ f(i,j) \le f(x+r,y+s) \le f_{med}(x,y) \\ 1 - \frac{f(x+r,y+s)-f_{med}(x,y)}{f_{max}(x,y)-f_{med}(x,y)} \\ for\ f_{med}(x,y) \le f(x+r,y+s) \le f_{max}(x,y) \\ 1 \\ f_{med}(x,y) - f_{min}(x,y) = 0 \\ f_{max}(x,y) - f_{med}(x,y) = 0 \end{cases} \quad (6)$$

The above equation presents asymmetric triangle window function. The asymmetry level depends of the divergence between $f_{med}(x,y) - f_{min}(x,y)$ and $f_{max}(x,y) - f_{med}(x,y)$. $f_{min}(x,y)$, $f_{max}(x,y)$, $f_{med}(x,y)$ are respectively, slightest, the maximal, and the median gain of all the input values *f(x + r; y + s) for r, s ϵ A* within the window A at disticit indexes *(x,y)*[17].

3. SUGGESTED HYBRID FILTER

The proposed Hybrid filter uses a hybrid noise reduction technique to estimate the center pixel by performing in a square-moving window, spatial filtering is used specified as kernel, as well as estimating designated, slid function and median filter in similar time. The following equation describes the mathematic model:

$$R(x,y) = \bar{I}(x,y) + k_1 * Err_1 + k_1\big(I(x,y) - \bar{I}(x,y)\big) + k_2(I(x,y) - \bar{\bar{I}}(x,y) \quad (7)$$

$$k_1 = \tanh(a_1 x Err_1) \quad (8)$$

$$k_2 = \tanh(a_2 x Err_2) \quad (9)$$

$$Err_1 = I(x,y) - (\bar{I}(x,y) + \bar{\bar{I}}(x,y))/2 \quad (10)$$

$$Err_2 = I(x,y) - \bar{\bar{I}}(x,y)) \quad (11)$$

Where: $\bar{\bar{I}}(x,y)$ =the local median filter
$I(x,y)$ =the observed image
$\bar{I}(x,y)$ =the local mean
k_1, k_2 =non-lineraty function
a_1, a_2=the control factors

For this reason, non-linearty function of (tanh (.)), sliding mode control (MSC) method and single neuron PID controller are employed in order to evaluate the appropriate gain profit that is related to the signal inaccuracy [24]-[26]. The framework of k is 0 to 1, therefore if the error is large, the extraction function will be large, and if the error is little, the output will be tiny because the gain is nonlinear, this function will be modest at this range. The control factors a1, a2 are used to lower the output of a nonlinear function in the range of 0 to 0.5, and which is the optimal value for removing mixed noise.

4. SIMULATION RESULTS

Two SAR pictures of various sizes, each quantized in 8 bits, are utilized in simulations in MATLAB to examine the implementation of this approach shown in Figures 1 and 2. The first SAR is a 256 by 256 picture of the "imageSAR1", as shown in Figure 1(a), and the second is a 366by 364 image of the "image SAR2", as illustrated in Figure 2(a). As illustrated in Figures 1(b) and 2(b), the original picture and a multiplicative noise with a uniformly distributed mean and variance (0.5) is multiplied and added salt and pepper with a variance (0.02) to the simulated images. Images in Figures 1(c) to 1(i) describe SAR1 image and Figures 2(c) to 2(i) illustrate the interpretation of the recommended hybrid filter resemble to all mean, median, the Lee and Frost, asymmetrical triangular fuzzy filter with median center (ATMED) fuzzy and Kuan filters.

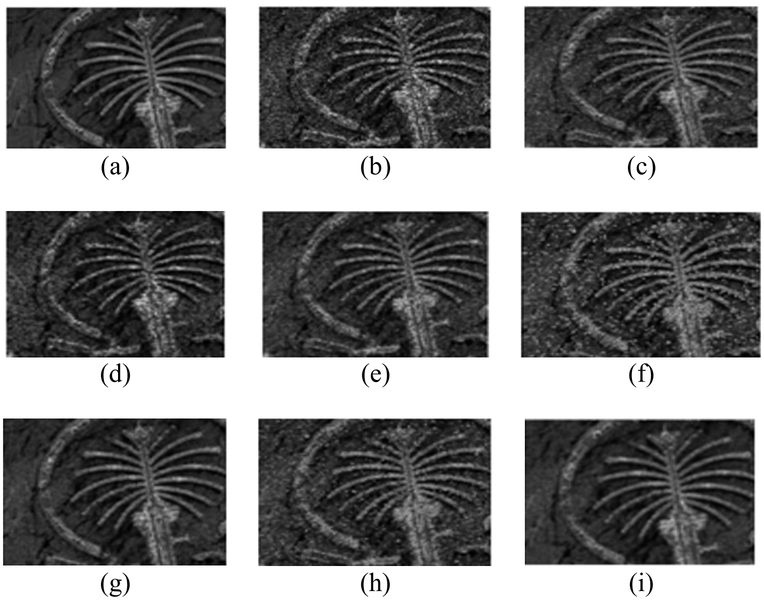

Figure 1. Present (a) raw image, (b) noisy image with variances with speckle=0.5 and (salt and pepper)=0.02, (c) effect of using frost filter, (d) effect of using median filter, (e) effect of using mean filter, (f) effect of using Lee filter, (g) effect of using ATMED filter, (h) effect of using kuan filer, and (i) state the suggested hybrid filter

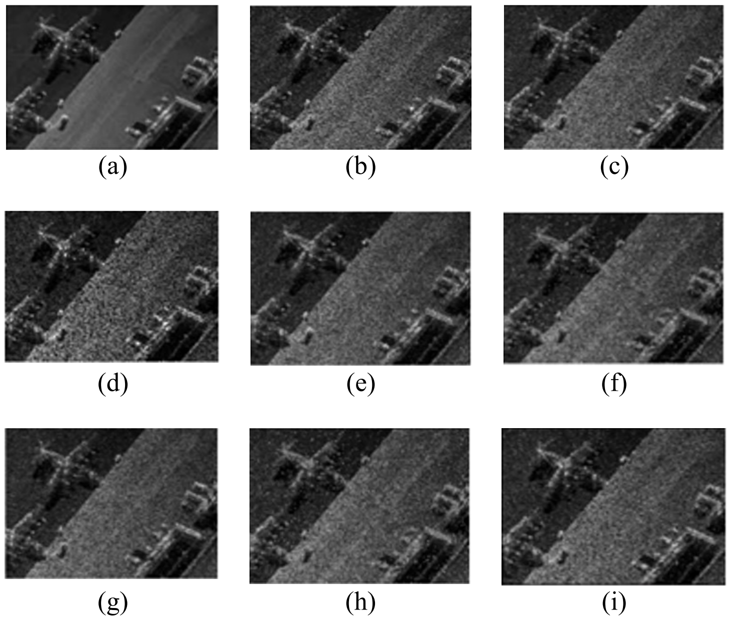

Figure 2. Present (a) raw image, (b) noisy image with variances with speckle=0.5 and (salt and pepper)=0.02, (c) effect of using frost filter, (d) effect of using median filter, (e) effect of using mean filter, (f) effect of using lee filter, (g) effect of using ATMED filter, (h) effect of using kuan filer,and (i) state the suggested hybrid filter

The following three parameters are specified and calculated for the purpose of objectively assess the outcome of these filters:

- To determine the overall amount of difference between two pictures, the mean square error is employed. A lower MSE implies that the disparity in the difference between the original image and the de-noised image is small. It goes like this [23].

$$MSE = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} (F(x,y) - \bar{R}(x,y)) \quad (12)$$

While $\overline{R}(x,y)$ and $F(x,y)$ emplying the values of the denosied primary image.

- The signal-to-noise ratio formula is a metric static for determining how effective the speckle noise to the process of reduction. The formula is as:

$$SNR = 10\, log_{10} \frac{\sum F^2(x,y)}{\sum (F(x,y) - \bar{R}(x,y))^2} \quad (13)$$

- The measure edge has been tought about preservation edge. More obviously, [23] have stated the parameter β as:

$$\beta = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} (\Delta F)x,y) - \overline{FX})(\Delta\bar{R}(x,y) - \overline{\Delta\bar{R}})}{\sqrt{\left[\sum_{i=1}^{M} \sum_{j=1}^{N} (\Delta F(x,y) - \Delta F)^2\right]\left[\sum_{i=1}^{M} \sum_{j=1}^{N} (\Delta\bar{R}(x,y) - \overline{\Delta\bar{R}})^2\right]}} \quad (14)$$

Where ΔF and $\Delta\bar{R}$ present the high-pass filter forms of F and $\bar{R}$ sequentially, and $\overline{\Delta F}$ and $\overline{\Delta\bar{R}}$ explicate the mean of the high-pass filter variety of F and $\overline{\Delta \mathrm{R}}$ severally, the sobel operator was approximated with a $3 * 3$ pixel standard approximation. Details about the Sobel high-pass filter applied for this objective may be found here [27].

All statistic boosted filters, including the Suggested filter, used a 3x3 kernel. The MSR, SNR, and assessment parameters were applied to the entire picture. The damping factor is set to 1 for the Frost filter, and the factors of control in the recommended filter are fixed to $a_1 = 0.02$ and $a_2 = 0.12$ to place the maximum profit up to 0.5, which is the optimal range value for estimating the optimum profit to eliminate speckle noise. Tables 1-4 abstracted simulation results of de-noise image SAR1 and image SAR2 accompanied by speckled variances of 0.5 and 0.7 and also the salt & pepper noise of variances ranged of 0.02 and 0.2, respectively and show that the proposed filter reject the speckle and salt & pepper unescorted by deleting crucial image borders or altering essential image information.

Table 1. The estimation of the filters with 3x3 windows for SARI1 with variances (speckle=0.5 and salt and ppaper=0.02)

Filters	SNR(db)	β	MSR
Noisy image	16.0229	0.1679	0.0322
Suggested hybrid filter	23.2793	0.2545	0.0047
Kuan filter	16.9485	0.0150	0.0254
Lee filter	16.6186	0.0325	0.0295
ATMED filter	22.5258	0.2318	0.0052
Frost filter	21.2918	0.2682	0.0074
Median filter	19.7322	0.1273	0.0106
Mean filter	20.4614	0.1065	0.0090

Table 2. The estimation of the filtered types with 3x3 windows for SARI1 with mixed noises for variances (speckle=0,7 and salt and pepper=0.2)

Filters	SNR(db)	β	MSR
Noisy image	11.9414	0.0979	0.0640
Suggested hybrid filter	19.9923	0.2545	0.0100
Kuan filter	16.9485	0.0150	0.0254
Lee filter	16.6186	0.0325	0.0295
ATMED filter	19.5258	0.1793	0.0130
Frost filter	17.4516	0.1631	0.0635
Median filter	19.076	0.1715	0.0124
Mean filter	18.6739	0.1454	0.0136

Table 3. The estimation of the filters using 3x3 windows for SARI2 with mixed noises for variances (speckle=0.5 and salt and pepper=0.02)

Filters	SNR(db)	β	MSR
Noisy image	11.9414	0.0979	0.0640
Suggested hybrid filter	19.9923	0.2545	0.0100
Kuan filter	16.9485	0.0150	0.0254
Lee filter	16.6186	0.0325	0.0295
ATMED filter	19.5258	0.1793	0.0130
Frost filter	17.4516	0.1631	0.0635
Median filter	19.0764	0.1715	0.0124
Mean filter	18.6739	0.1454	0.0136

Table 4. The estimation of the filters using 3x3 windows for SARI2 with variances (speckle=0.7 and salt and pepper=0.2)

Filters	SNR(db)	β	MSR
Noisy image	14.2539	0.1091	0.0376
Suggested hybrid filter	23.2793	0.1667	0.0050
Kuan filter	16.5455	0.0250	0.0254
Lee filter	16.9186	0.0325	0.0295
ATMED filter	22.0303	0.1280	0.0063
Frost filter	20.1139	0.1624	0.0375
Median filter	19.7322	0.1273	0.0106
Mean filter	19.7322	0.1273	0.0106

5. CONCLUSION

This study proposes a hybrid filter based on a nonlinear function for removing mixed noise from digital pictures while maintaining edge preservation. Lower mean square error, greater signal to noise ratio, as well as a c. The proposed filter exhibit good performance on two sorts of images. According to experimental data, the proposed filter recovers the SAR image substantially superior comparing prior noise reduction filters.

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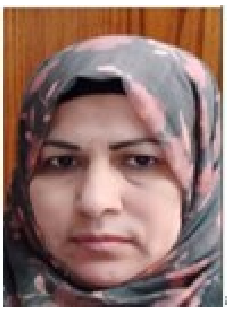

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