Impulse noise removal for SAR images using PRNM

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***Abstract* -** Uncertainties are the main difficulties of impulse noise analysis. This fact makes image denoising a difficult task. Understanding the uncertainties can improve the performance of image denoising. CM filtering and existing filtering methods like median filtering all can serve at an average level of noise that they can produce an average level of improvement in PSNR value of denoised image. The level that obtained by the methods which are currently used for noise removal does not provide enough details of the original image for SAR image noise analysis. So, still there is a requirement of an efficient filtering which can produce more related details from the original images. Pseudo random noise masking is the proposed filtering technique here which uses standard deviation and similarity parameter 'S' for the removal of impulse noise from SAR images. The detection process which is related to similarity index can produce more efficient impulse noise removal which can be shown through the PSNR value comparison. The pseudo random noise masking filter (PRNM) which is designed using similarity parameter 'S' can provide efficient removal of an SAR image in which above 95% of pixels were affected by impulse noise.

Keywords—Cloud model (CM), image denoising, impulse noise, median filter. pseudo random noise masking,

I. Introduction

Impulse noise is a spark that affects the contents of digital images at two stages i.e. image acquisition and image transmission. Impulse noise distorts image pixels while replacing the original value either by fixed value or random value. Mostly, it affects the SAR images badly. Impulse noise is the main type of noise which affects most of the SAR images. This leads to the analysis of the SAR images very difficult.

Salt and pepper noise is a noise which comes under the category of fixed value impulse noise, in which the pixel value takes either the highest value 255 or the lowest value 0.

Impulse noise, often found in digital transmission and storage, can be described by the following model:

$$I = (1 - e)S + eN \qquad (1)$$

In the above equation, I denotes corrupted image pixel value. S denotes original pixel value. N denotes noise value and e denotes error value.

From last two decades, many methods for removing impulse noise have been proposed by any authors. But those methods are just used to remove the impulse noise from the general images with low noise level.

II. Literature Survey

A method which is known as vector directional filters [18], has two types of constraints (i.e.) one for magnitude and other one for direction. Generally, there are two types image processing namely single image processing and multi channel processing. By using this vector directional filters, process of noise removal can be performed separately. It does not preserve the finer details which present at the edges of the original image due to which reduction in PSNR value.

A median-based filter, progressive switching median (PSM) filters [12] are developed to remove salt–pepper impulse noise from the corrupted images. This PSM filtering technique is carried out in two parts. Initially a switching scheme - an impulse detection algorithm is used before filtering. In this step, only a part of pixels were selected for analysis and then filtered. After that the second part is started and in this, both the impulse detection and the noise filtering procedures are carried out through various numbers of iterations. Simulation results of this PSM demonstrate that this algorithm is better than traditional median based filters. It creates new pixel values which are not present in the original image. Low Peak signal to noise ratio occurs for highly corrupted images.

Previous median-based impulse detection techniques work well for fixed-valued impulses only but poorly for random valued impulse noise or vice versa. operator, which forms estimates based on the differences between the current pixel and the outputs of center-weighted median (CWM) filters with varied center weights are then developed [5].The center weighted median(CWM) filter which is a weighted median filter which is giving more weight to the center value of each window. This filter can preserve image details by suppressing additive white Gaussian noise or impulse type noise. This filter gives more weight to the central value of a window, and this method is very easier to design. Extensive simulations show that this method of filtering works well in both types of impulses with various noise ratios.

Then a method for impulse noise removal is proposed for commercial use, where a robust estimator of the variance, MAD (median of the absolute deviations from the median), is modified [16]. And this is used to efficiently separate noisy pixels from the image details. The major advantages of this method are, 1) It does not require any previous training or optimization.2) This method is free of varying parameters.3) It can be used for the removal of all types of impulse noise.4) Low complexity. 5) This method achieves high filtering performance. But it has high consumption of CPU time which creates difficulty in the analysis of SAR images.

After that a new directional weighted median filter for removal of random-valued impulse noise has been developed [4]. In this filtering method, the differences between the current pixel and its neighbors aligned with four main directions are taken into consideration and that will be joined with the weighted median filter for the removal of impulse noise. This method can be used efficiently for gray images but works very poorly for colour images.

The above filtering techniques of impulse noise removal do not preserve the original image's finer details and not giving efficient PSNR value too. This leads to the requirement of efficient algorithm for impulse noise removal. This paper proposes a technique called Pseudo random noise masking filtering which produces high PSNR at highly corrupted noise level with very low consumption of CPU time.

III.Cloud Model

Recently, a method of detection and filtering of impulse noise removal which is known as cloud model filter has been proposed. The CM is a natural-language cognitive model with uncertainty. It combines the fuzziness and the randomness, and forms an intermapping between the qualitative and quantitative information.

The cloud relies on three parameters to deliver the characteristics based on qualitative concept. i.e., the expected value Ex, entropy En, and hyperentropy He. The expected value Ex is the expectation of the cloud drop's distribution in the domain. This expected value determines the drops that can give the better required details.

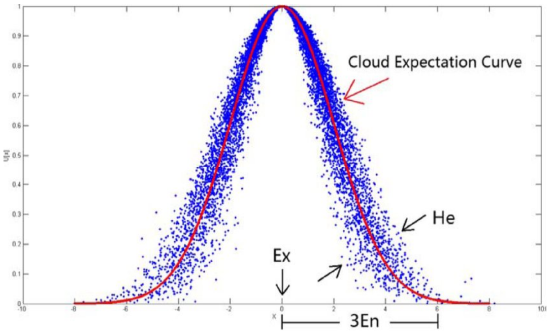


Fig. 1 Cloud C (0, 2, 0.3).

En denotes the uncertainty measurement of the qualitative concept. It is determined by both characteristics i.e., the randomness and the fuzziness of the concept. If any of the drops is acceptable by the concept that value region can be given by En. Meanwhile, it reflects the correlation of the randomness and the fuzziness of the concept. He is the uncertainty measurement of En. For example, lets denote a cloud C(Ex=0, En=2, He=0.3). This cloud can be given by the following Fig 1.

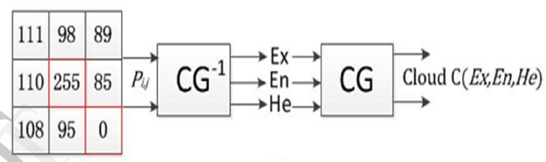


Fig. 2 Calculated the cloud that represents the observed neighborhood.

The drops are creating the cloud. While the drops are approaching Ex, there is a probability of increase in certainty degrees and contribution degrees [21]. The drops present within [Ex-3En, Ex+3En] take up to 99.99% of the whole quantity and contribute 99.74% to the concept. From this we can say that, the drops, which are presented out of range [Ex-3En, Ex+3En], and the contributions to the concept due to that can also be neglected. This concept is known as "The 3En rule".

All the drops and the expectations of certainty degrees due to that drops will produce a curve, and that curve can be known as the cloud expectation curve (CEC). For example, the red line denotes the certainty expectation curve of cloud C (Ex=0, En=2, He=0.3) in Fig 1.

To have the clear details about certainty degrees, consider the following pixel block. In the Fig 2. CG denotes the cloud model generator and the generated cloud curve can be shown as in Fig 3.

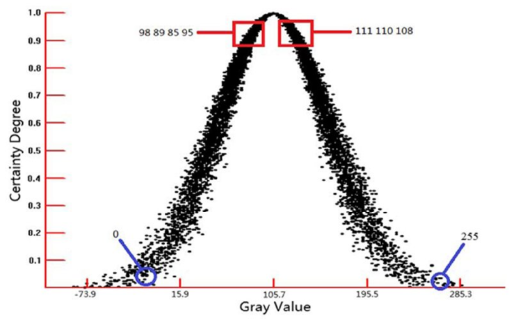


Fig. 3 Cloud C (105.7, 44.9, 47.8) represents the neighborhood in Fig. 2.

The certainty degrees for the uncertainty detection can be given as follows in Table 1. As in the Table 1 the certainty degrees of 255 and 0 are very less compared to other values. The block diagram of the impulse noise removal process based on cloud model can be shown in Fig 4.

As denoted in Fig 4., Initially all the pixels are read out. Then Ex and En values are found out. By having these calculated values of Ex and En, wmax and wmin values are calculated.

TABLE. 1

Representation of Certainty Degree of Each Pixel

Gray value	Certainty degree
111	0.99298
98	0.99298
89	0.93352
110	0.99536
255	**0.00400**
85	0.89963
108	0.99865
95	0.97222
0	**0.06297**

If the particular pixel which is taken, relies between the interval wmin and wmax, then that pixel is said to be an unaffected one.

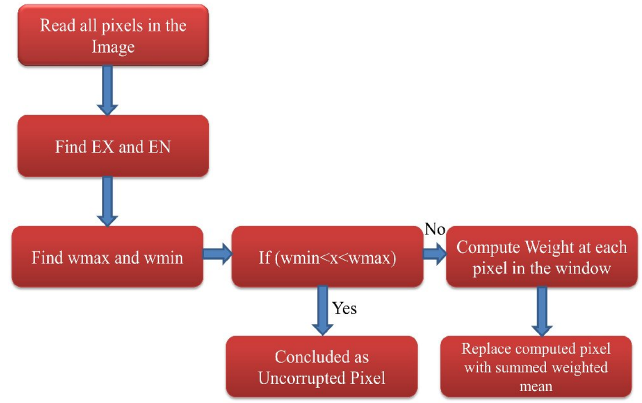


Fig. 4 Cloud model based impulse noise removal process

If the particular pixel value does not occur within the range, then the process of WFM filter comes into act. Using this filtering technique, mean weight for this pixel is calculated and then that mean weight replaces the noisy pixel.

IV. Pseudo Random Noise Masking Technique

Impulse noise removal using pseudo random noise masking has been proposed in this paper. Pseudo noise masking deals the noise removal analysis with the help of directional vectors.

The overall analysis based on the pseudo random noise masking has been divided into three main modules i.e. direction vector analysis, similarity parameter analysis and Detection of noise certainty for the pixel which is taken for the analysis.

The flow of process of removing impulse noise from SAR images which is shown in the Fig 5., can be explained with the following sections.

A. Direction Vector Calculation

Initially, all the pixels in the image has been read out. To carry on the process of impulse noise removal, a k*k window will be created next. After creating that k*k window, the center pixel will be noted for which the impulse noise analysis to be carried out further. Through that center pixel, there are four lines can be tracked out as shown in the following Fig 6.

Each tracked line can give a set of pixel elements. Each of them can be named as a directional vector. The four directional vectors for the window shown in Fig 6. are given as,

D1 = [102 209 102 118 105 6 108 108 109]
D2 = [131 100 89 106 105 102 180 98 34]
D3 = [232 37 228 102 105 103 138 74 197]
D4 = [100 100 102 103 105 107 22 95 108]

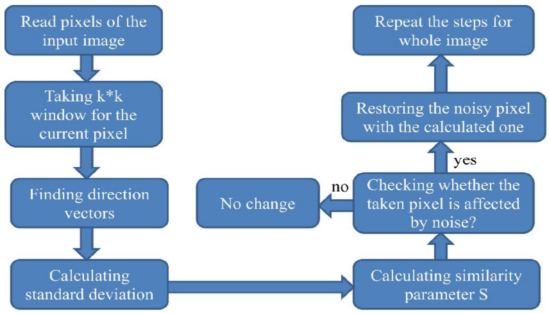
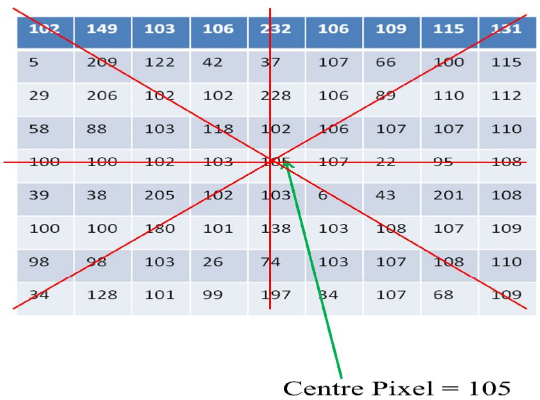


Fig. 5 Pseudo random noise masking based impulse noise removal



102	149	103	106	232	106	109	115	131
5	209	122	42	37	107	66	100	115
29	206	102	102	228	106	89	110	112
58	88	103	118	102	106	107	107	110
100	100	102	103	105	107	22	95	108
39	38	205	102	103	6	43	201	108
100	100	180	101	138	103	108	107	109
98	98	103	26	74	103	107	108	110
34	128	101	99	197	34	107	68	109

Fig. 6 Identification of directional vectors

Next, the center pixel which is present in the directional vectors will be removed. After removing the center pixel the directional vectors will look like as follows,

D1 = [102 209 102 118 6 108 108 109]
D2 = [131 100 89 106 102 180 98 34]
D3 = [232 37 228 102 103 138 74 197]
D4 = [100 100 102 103 107 22 95 108]

Then the pixel elements in the vectors are sorted in ascending order and then the smallest and the largest pixel elements are removed. Then the vectors can be given as,

R1 = [102 102 108 108 109 118]
R2 = [89 98 100 102 106 131]
R3 = [74 102 103 138 197 228]
R4 = [95 100 100 102 103 107]

B. Similarity Parameter Analysis

In this second module of impulse noise removal process, the value of similarity index parameter has been calculated. For calculating similarity index parameter, it is necessary to find out the optimum direction and corresponding directional vector.

To find out the optimum direction, standard deviations of all four directional vectors have to be calculated first. The four standard deviation values are calculated and stored as follows,

STD1 =*std(*[102 102 108 108 109 118]*)*
STD2 =*std(*[89 98 100 102 106 131]*)*
STD3 =*std(*[74 102 103 138 197 228]*)*
STD4 =*std(*[95 100 100 102 103 107]*)*

The optimum direction for the analysis is defined as the direction which corresponds to the minimum value of standard deviation. After finding the optimum direction, the pixel values in that direction are read out.

Similarity index parameter which is denoted by S is calculated using the following summation,

$$S=\sum \text{abs}\left(\frac{(\text{Dop}-\text{Xcp})}{255}\right) \qquad (2)$$

Where, Xcp–current pixel under process

Dop–Pixels in the optimum direction

C. Detection of Noise Certainty

Finally in the removal of impulse noise from SAR images, it is very important to check whether the pixel is affected by noise i.e., noise certainty. This noise certainty can be found out by having a threshold value.

The threshold value for the analysis depends the size of the window which is taken for the analysis and also the similarity parameter S. The threshold value T checks whether a particular pixel is affected by impulse noise or not as follows,

$$\text{Xout} = \begin{cases} Xor \;\; , if\ S \in T \,, (0 \le T \le k-3) \\ Xno \qquad\qquad\qquad\qquad else \end{cases} \qquad (3)$$

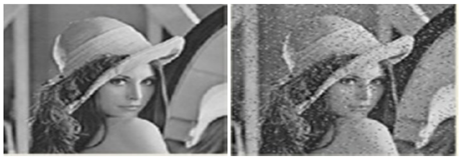
Where, Xor - original pixel

Xno - noisy pixel

The above formula checks whether the pixel is noisy or original and then that pixel is restored by using WFM filter which is mentioned earlier in the existing method, if and only if it is affected by noise. The above three modules of analysis and calculations are carried out for the whole SAR image to retrieve the original SAR image from the SAR image which is affected by impulse noise.

V. Simulation Results

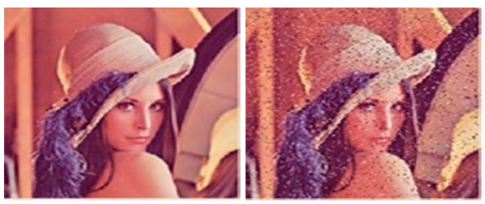
The restoration performance can be figured out by using PSNR value comparison with the existing method’s solution. The executed results are shown through the following snapshots. Initially the proposed method is executed with lena gray image (Fig 7).Then the proposed pseudo random noise masking filtering has been applied for the lena colour image. The execution on that image can be shown in Fig 8.



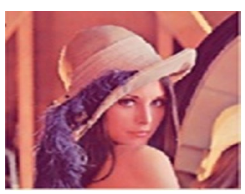
(a) (b)

(c)

Fig. 7 Execution of PRNM filter - Removal of impulse noise from lena gray 7(a) Original image 7(b) noisy image 7(c) Denoised image

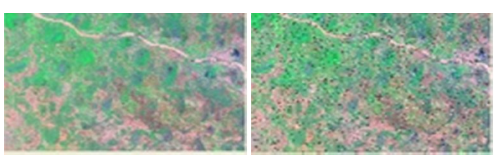


(a) (b)



(c)

Fig. 8 Execution of PRNM filter - Removal of impulse noise from lena colour 8(a) Original image 8(b) noisy image 8(c) Denoised image



(a) (b)

(c)

Fig. 9 Execution of PRNM filter - Removal of impulse noise from SAR image 9(a) Original image 9(b) noisy image 9(c) Denoised image

TABLE. 2

Performance Comparison

Noise density (%)	**Lena gray**		**Lena colour**		**SAR image**	
	CM	**PRNM**	**CM**	**PRNM**	**CM**	**PRNM**
10	44.34	78.59	46.45	78.65	47.83	80.23
20	37.69	76.64	40.11	76.72	41.12	78.67
30	33.94	74.03	36.24	74.28	37.18	76.50
40	31.36	71.45	33.66	71.41	37.50	73.83

Table. 2 indicates the comparison of cloud model filtering and also proposed PRNM filtering based on the PSNR values for basic lena gray and lena colour images. Fig 10. Shows the execution snap of impulse noise removal process from lena image using PRNM filter.

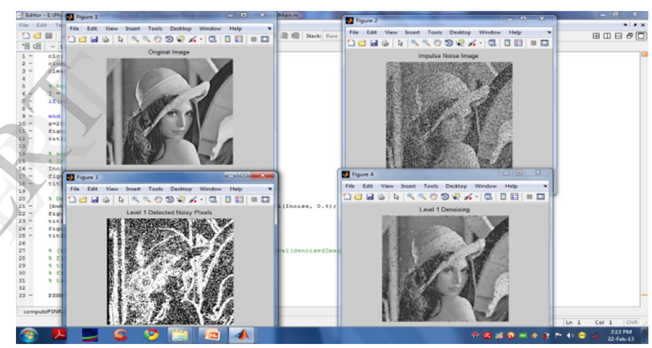


Fig. 10 Execution of PRNM filter

Table 3. shows the application of cloud model and PRNM filtering with various noise levels on the sample SAR image. It indicates improvement on PSNR values by the use of PRNM filter.

VI. Conclusion

The impulse noise removal process for SAR images is having some difficulties for long years. Since four to five years some methods have been proposed for impulse noise removal from SAR images. These methods can give results somewhat acceptable but not well up to the limit for all the post processing of SAR images.

The proposed filter which is based on pseudo random noise masking can produce much better results. By using this method the original image details can retrieve up to 98%.

Though the proposed PRNM method can give better PSNR values, it consumes more time to execute which can be viewed through CPU time consumption.

In future work, the computation time of the proposed filter can be reduced by using some shorter computation steps instead using standard deviation analysis.

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