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AN ADAPTIVE THRESHOLD INTENSITY RANGE FILTER FOR REMOVAL OF RANDOM VALUE IMPULSE NOISE IN DIGITAL IMAGES

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ABSTRACT

A novel approach for denoising digital images corrupted by impulse noise is presented in this brief. The proposed approach uses an efficient technique to identify pixels corrupted by random noise. This is done by setting an intensity range for the center pixel of the selected window and checking whether the number of pixels which fall within this range is above or below a specified threshold. If the condition for an uncorrupted pixel fails in the selected window, the window size is increased and threshold is adaptively changed. Experimental evaluation using MATLAB revealed that the proposed approach demonstrates better Peak Signal to Noise Ratio (PSNR) improvement for higher noise densities when compared to the best of the approaches used for comparison. Visual interpretation of output images revealed that our approach preserved edges and fine details when compared to the existing algorithms.

Keywords: *Random Valued Impulse Noise, Intensity Range, Soft-switching, Rank order, Peak Signal to Noise Ratio.*

1. INTRODUCTION AND RELATED WORK

Digital images are highly corrupted by Impulse noise while during acquisition and transmission. The impulse noise can be classified under: salt and pepper noise and random valued noise. The pixel which is identified as corrupted and takes either maximum or minimum gray level is classified as pixel corrupted by salt and pepper noise. The corrupted pixel which takes any value between 0 and 255 is classified as Random Valued Impulse Noise (RVIN). Further processing of an image for its enhancement needs this noise to be removed; otherwise the performances of image processing tasks such as segmentation, feature extraction, object recognition, etc. are severely degraded by noise [1]. Though there are various algorithms for removal of RVIN they are not efficient at high noise densities. So we concentrate on design of efficient algorithm for RVIN removal in images. Eng H.L and Ma [2] proposed a Noise Adaptive Soft-switching Median (NASM) filter. The filter uses a soft-switching noise-detection scheme to identify each pixel's characteristic, followed by proper filtering operation. In the noise-detection scheme, global (i.e., based on the entire picture) and local (i.e., based on a small window) pixel statistics are utilized in the first and the remaining two decision-making levels respectively.

Chen and Hong Ren Wu [3] proposed an Adaptive Center Weighted Median Filter (ACWMF). Jianjun Zhang[4] proposed a two phase median filter for removal of RVIN. The filter removes impulse noise from degraded images in 2 phases. In the first phase adaptive Center Weighted Median Filter (CWMF)[12] is used to identify noisy pixels. In the noise removal phase he used an iterative method based on median value.

Crnojevic et al proposed a median filter which performs filtering operation on a pixel to pixel basis. The proposed approach considers median of absolute deviations to identify the corrupted pixel. The basic principle of the proposed

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filter(PWMAD)[14] is to estimate the deviations of a pixel value from the median of the selected window. Though the filter performs better noise removal at low densities, it blurs the image at higher noise densities.

Jianjun Zhang [4] proposed an adaptive switching median filter for removal of RVIN. The novelty of the design is that setting global threshold is not necessary as in the case of conventional switching median filters. The algorithm works well for noise densities upto 60%.

Various rank order filters for removal of RVIN were proposed during various periods. Garnett et al, [5] proposed a TRIlateral Filter which uses Rank Order Absolute Difference statistics(ROAD-TRIF), Y.Dong etal[6] proposed a filter based on Rank Order Logarithmic Difference statistics and Edge-Preserving Regularization method(ROLD-EPR) and Hancheng Yu et al[15] proposed Rank order filter combining absolute and logarithmic differences statistics and used bilateral filters for filtering. The filter in [15] used image processed by Standard Median Filter(SMF)[16] as reference. The relative difference between input image and the reference image is calculated. The pixels which have this difference greater than a set threshold are identified as noisy. In second phase the corrupted pixels are removed using simple weighted mean filter. The algorithm in [15] performs well compared to [5] and [6]. However setting threshold for detecting noisy pixels poses a major problem.

A two-stage iterative method for RVIN is proposed by Chan et al[13]. The technique in [13] uses ACWMF[3] to identify the noisy pixels in phase 1. In phase 2 EPR technique is employed to preserve edges and fine details. The proposed filter(ACWMF-EPR) performs better compared to non-linear filters and preserves edges well.

Thivakaran and Chandrasekaran[7] proposed a new technique for removal of RVIN based on nonlinear Adaptive Median filter (AMF). The filter is more effective for small window, but for large window and in case of high noise densities it gives rise to more blurring.

Kalavathy and Suresh[8] Proposed a impulse noise removal method based on adaptive median filter and multistage median filter or the median filter based on homogeneity information are called “decision based” or ‘switching’ filters . Here, the filter identifies possible noisy pixels and then replaces them with median value or its variants by leaving all the other pixels unchanged. On replacing the noisy pixels with some median value in their vicinity, the local features such as the possible presence of edges are not taken into account. Hence details and edges are not preserved satisfactorily especially when the noise level is high.

Saradhadevi and Sundaram[9] Proposed a new two-stage noise removal technique to deal with impulse noise. An Adaptive Neuro-Fuzzy Inference System(ANFIS) is designed for fast and accurate noise detection such that various widespread densities of noisy pixels can be distinguished well from the edge pixels. The proposed ANFIS uses Modified Levenberg-Marquardt Training Algorithm for reducing the execution time. After suppressing the impulse noise, the image quality enhancement is applied to enhance the visual quality of the resultant images. It consists of fuzzy decision rules based on the Human Visual System (HVS) for image analysis and Neural Network (NN) for image quality enhancement. If a noise-corrupted pixel is in the perception sensitive region, the proposed NN module is applied to this pixel for further quality compensation. The proposed approach effectively eliminates the impulse noise while preserving most fine details.

Bhavana Deshpande et al[10] proposed a Modified median filter. The filter incorporated a decision based technique in which the corrupted pixels are replaced by either the median pixel or neighborhood pixel. At higher noise densities, the median value may also be a noisy pixel. In that case, median of already processed neighborhood pixels are used for replacement. This provides good correlation between the corrupted pixel and neighborhood pixel which in turn gives rise to better edge preservation. To remove any sort of Grayness ambiguity and Geometrical uncertainty present Fuzzy Rule based approach is used. However the restored images still contains some traces of salt-and-pepper noise.

Harale and Chitode[1] proposed an efficient impulse noise removal algorithm giving more weight to the central value of each window. The proposed filter in [1] gives better image restoration compared to the conventional median filter [11] and CWMF [12] for both low and high noise densities. However the algorithm suffers from setting a proper threshold, as it has to be set manually and depends on the type of image.

In this brief we propose an Adaptive Threshold Intensity Range Filter(ATIRF) which uses two stages to remove RVIN. In the first stage

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a novel detection technique is employed which detects noisy pixel based on the number of pixels which lie within a selected range of the center pixel in the selected window. In the second stage we perform filtering by replacing the center pixel with the mid-point out of maximum and minimum intensity value of uncorrupted pixels in the selected window.

2. PROPOSED ATIRF

The proposed ATIRF approach uses two stages to detect corrupted pixels. In the first stage a novel detection technique is used to identify the corrupted pixel. At first a 3 X 3 window is selected and the following strategy is used to detect whether the center pixel is noisy or uncorrupted. An intensity range is selected and the number of pixels which lie within this range is estimated. If the count is more than a specified threshold the center pixel is identified as uncorrupted. On the other hand the window size is increased in steps of 2. For each increment of window size, the condition for uncorrupted pixel is checked with a different threshold. The incrementing of window size is done till the window size reaches 9. The processing is stopped with a particular window once the condition for uncorrupted pixel is satisfied.

In the second stage, filtering is applied to the selected window to replace the center pixel with the average of minimum and maximum intensity of uncorrupted pixels. The steps followed in the proposed ATIRF approach is as follows.

Steps

1. Select a 3 X 3 window in which intensity value of center pixel is *l*.
2. Count the No. of pixels(T_1) in the 3 X 3 window which falls in the range ($l - 3, l + 3$).
3. If T_1 >= 6, the center pixel is uncorrupted, else increase the window size by 2 i.e., 5 X 5 window
4. Count the No. of pixels(T_2) in the 5 X 5 window which falls in the range ($l - 5, l + 5$).
5. If T_2>= 12, the center pixel is uncorrupted, else increase the window size by 2 i.e., 7 X 7 window
6. Count the No. of pixels(T_3) in the 7 X 7 window which falls in the range ($l - 7, l + 7$).
7. If is T_3>= 8, the center pixel is uncorrupted, else increase the window size by 2 i.e., 9 X 9 window
8. Count the No. of pixels(T_4) in the 9 X 9 window which falls in the range ($l - 9 , l + 9$).
9. If T_4>=12, the center pixel is uncorrupted, else corrupted.

3. ILLUSTRATION OF ATIRF ALGORITHM

3.1. Detection Stage

The iterations in the proposed ATIRF algorithm begins from the first pixel by selecting a 3 X 3 window with the center pixel as the processing pixel. The following processes are done to detect whether the processing pixel is corrupted or not. To illustrate the methodology, a 9 x 9 window which consists of the intensity values of Lena image is considered as shown below.

190	190	190	193	197	167	94	67	75
192	190	192	200	166	97	68	72	80
197	197	196	166	101	76	85	87	85
197	203	190	107	81	82	88	83	80
201	189	155	202	91	94	101	81	110
194	152	116	107	107	101	97	86	83
152	105	116	114	116	110	105	101	59
103	109	101	117	120	122	117	110	100
99	112	114	118	126	129	125	116	117

In the selected 3 X 3 window the center pixel is the processing pixel and following steps are followed to identify whether it is noisy or uncorrupted.

107	81	82
202	91	94
107	107	101

Case i) Let the intensity value of the processing pixel be *l*. Then a range (l-3, l+3) is chosen and the number of pixels(T_1) which fall within this range in a selected 3 X 3 window is counted. T_1 is checked to find whether it is greater than or equal to 6. If T_1 is less than 6, increase window size by 2.

Range-1:
Center pixel-3, Center pixel+3
Center pixel : 91 (Range-1: 88,94)

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No. of pixels(T_1) in the 3 X 3 window which falls in the Range-1= 1
Since T_1< 6, increase the window size by 2 (ie.5X5)

196	166	101	76	85
190	107	81	82	88
155	202	91	94	101
116	107	107	101	97
116	114	116	110	105

Case ii) Then a range (*l*-5, *l*+5) is chosen and the number of pixels(T_2) which fall within this range in the 5 X 5 window is counted. T_2 is checked to find whether it is greater than or equal to 12. If T_2 is less than 12, increase window size by 2.

Range-2:
Center pixel-5, Center pixel+5
Center pixel : 91 (Range-2: 86,96)
No. of pixels(T_2) in the 5 X 5 window which falls in the Range-2 = 3
Since T_2 < 12, increase the window size by 2 (ie. 7 X 7)

190	192	200	166	97	68	72
197	196	166	101	76	85	87
203	190	107	81	82	88	83
189	155	202	91	94	101	81
152	116	107	107	101	97	86
105	116	114	116	110	105	101
109	101	117	120	122	117	110

Case iii) Then a range (*l*-7, *l*+7) is chosen and the number of pixels(T_3) which fall within this range in the 7 X 7 window is counted. T_3 is checked to find whether it is greater than or equal to 8. If T_3 is less than 8, increase window size by 2.

Range-3:
Center pixel-7, Center pixel+7
Center pixel : 91 (Range-3: 84,98)
No. of pixels(T_3) in the 7 X 7 window which falls in the Range-3= 6
Since T_3 < 8, increase the window size by 2 (ie. 9 X 9)

190	190	190	193	197	167	94	67	75
192	190	192	200	166	97	68	72	80
197	197	196	166	101	76	85	87	85
197	203	190	107	81	82	88	83	80
201	189	155	202	91	94	101	81	110
194	152	116	107	107	101	97	86	83
152	105	116	114	116	110	105	101	59
103	109	101	117	120	122	117	110	100
99	112	114	118	126	129	125	116	117

Case iv) Then a range (*l*-9, *l*+9) is chosen and the number of pixels(T_4) which fall within this range in the 9 X 9 window is counted. T_4 is checked to find whether it is greater than or equal to 15.

Range-4:
Center pixel-9, Center pixel+9
Center pixel : 91 (Range-4: 82,100)
No. of pixels(T_4) in the 9 X 9 window which falls in the Range-4 = 14
Since T_4 < 15, the center pixel is assumed to be corrupted.

3.1. Filtering Stage

107	81	82
202	91	94
107	107	101

- Consider the selected 3 X 3 window.
- Check whether there is any uncorrupted pixel. In the above case 107, 107, 107 & 101 is assumed to be uncorrupted based on the proposed detection technique.
- Replace the center pixel by the average of minimum and maximum pixel values which are uncorrupted.
  (107 + 101)/2 = 104.
- Replace the center pixel by 104.

Actual pixel value is 105

4. EXPERIMENTAL RESULTS

The Proposed ATIRF discussed in section II is tested on three different images viz., *Lena*,

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Boat and *Baboon* for three different noise densities viz., 20%,40% and 60%. The intensity values of all the gray level test images are maintained at 8 bits. To evaluate the performance of the proposed ATIRF, we filtered the noisy images using SMF[16], ACWMF[3], PWMAD[14], ACWM-EPR [13], ROAD-TRIF [5], ROLD-EPR [6] and RORD-WMF [15] approaches and compared. The parameters of the filters used for comparison are taken as the values published in the references mentioned and slightly modified according to the test images and noise densities.

The parameter used for comparison is PSNR defined in Equation (1)

$$PSNR\ in\ dB = 10\ \log_{10}\left(\frac{255^2}{MSE}\right) \quad (1)$$

Where

MSE – Mean Square Error and is defined as in Equation (2)

$$\text{MSE} = \frac{\sum_i \sum_j \left(Y(i,j) - \overline{Y}(i,j)\right)^2}{M\ X\ N} \quad (2)$$

M X N is size of the image,

Y represents the original image,

$\overline{\text{Y}}$ denotes the de-noised image,

Table 1. Average PSNR Values of Lena, Boat And Baboon Images Denoised Using Proposed ATIRF And Previous Approaches For Noise Density- 20%, 40% And 60%

Algorithm	Lena			Boat			Baboon		
	20%	40%	60%	20%	40%	60%	20%	40%	60%
SMF	31.20	27.75	22.66	24.54	22.72	19.12	22.58	20.43	19.27
ACWMF	34.98	29.26	22.70	27.32	23.55	19.45	24.20	21.60	19.56
PWMAD	34.90	31.26	25.32	27.15	23.79	21.21	23.70	21.61	19.85
ACWM-EPR	34.95	31.35	25.78	27.49	24.66	21.36	24.02	21.65	19.70
ROAD-TRIF	35.02	31.30	26.70	27.65	24.67	21.89	24.23	21.68	19.81
ROLD-EPR	35.60	31.60	27.82	27.80	24.74	22.65	24.49	21.92	20.38
RORD-WMF	36.18	32.03	28.01	28.26	25.04	23.32	24.86	22.06	20.43
Proposed ATIRF	**37.95**	**35.93**	**34.36**	**36.59**	**34.84**	**33.35**	**32.67**	**31.35**	**30.26**

To improve the validity of the results we have run 10 trials for each filter for all the input test images. This was done by corrupting the input image for a specific noise density 10 times. Since noise is a random variable there will be a slight variation in the intensity values of the corrupted images taken in the ten trials. These images are filtered by the proposed and state-of the art filters. At the final step average out of these ten trials is estimated and is shown in Table 1. A graphical representation of PSNR against various noise densities of ATIRF and previous approaches is shown in Figure 1.It is seen that our ATIRF approach demonstrates better PSNR estimate compared to all other previous approaches both at low and high noise densities.

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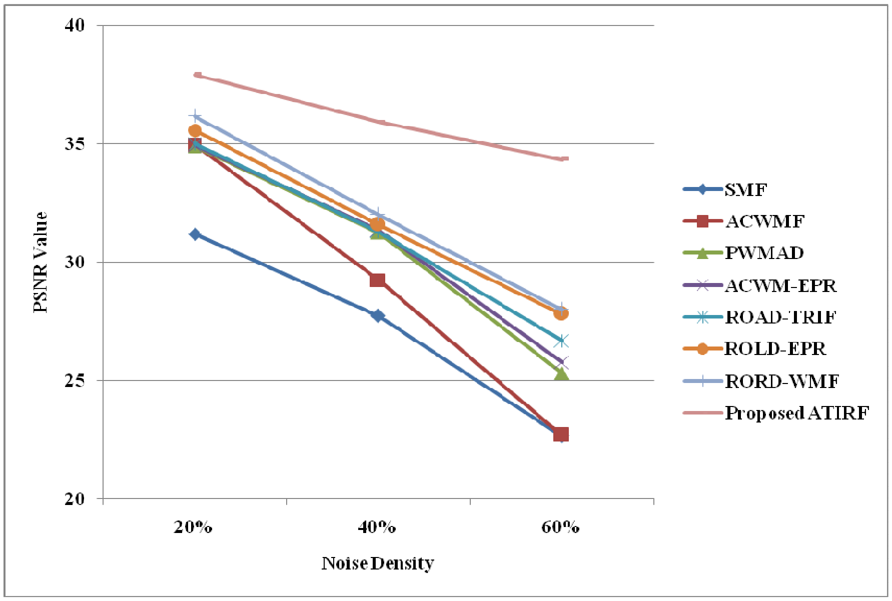

Figure 1: PSNR Comparison Of Output Lena Image Restored By Proposed ATIRF And Prior Arts Against Varying Noise Densities.

To evaluate the visual quality of output image, the corrupted Lena image of different noise densities (5%, 10%, 20%, 30%, 40%, 50% and 60%) were taken and restored using our ATIRF approach which is shown in Figure 2. Figure 2(a) represents the input and restored image for a noise density 5%, Figure 2(b) represents the input and restored image for noise density 10%, Figure 2(c) represents the input and restored image for noise density 20%, Figure 2(d) represents the input and restored image for noise density 30%, Figure 2(e) represents the input and restored image for noise density 40%, Figure 2(f) represents the input and restored image for noise density 50% and Figure 2(g) represents the input and restored image for noise density 60%.

Noise Density(%)	Corrupted Image	Denoised Image	PSNR in dB
5			40.005
	(a)		
10			39.183

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(b)			
20			37.947
(c)			
30			36.849
(d)			
40			35.927
(e)			
50			35.172
(f)			
60			34.36
(g)			

Figure 2: Output Images Restored By Proposed ATIRF For Varying Noise Densities (A) 5% (B) 10% (C)20% (D)30% (E)40% (F)50% (G) 60%.

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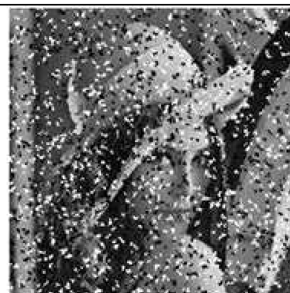
In addition, we have evaluated the detail and edge preservation effect of the proposed ATIRF and previous approaches. This was done by comparing Lena and Boat images denoised using ATIRF and previous filters for a noise density of 60% and shown in Figure 3. It is seen from Figure 3 that the performance of SMF is poor compared to all other approaches. ACWMF and ROAD-TRIF approaches show similar performance, however more noise patches are seen in these filters compared to PWMAD and ROLD-EPR approaches. The proposed ATIRF approach produces better image with very few noise patches. Also the edges are preserved well in case of images filtered by our ATIRF approach. This can be seen well from the zoomed portion of output of part of Lena image processed by ATIRF approach for 20% and 50% noise as shown in Figure 4.

Algorithm	Lena	Boat
SMF		
ACWMF		
PWMAD		
ACWM-EPR		

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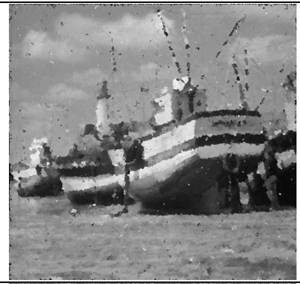
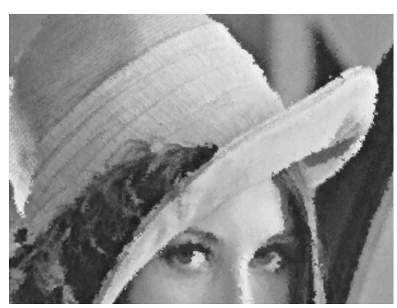
ROAD-TRIF		
ROLD-EPR		
RORD-WMF		
Proposed ATIRF		

Figure 3: Output Of Lena And Boat Images Restored By Proposed ATIRF And State-Of The Art Filters For 60% Noise Density.

(a)



(b)

Figure 4: Output Of Part Of Lena Image Processed By Proposed ATIRF Approach For (A) 20% Noise And (B) 50% Noise.

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5. CONCLUSION

A novel technique for removal of RVIN in digital images using adaptive intensity range with changing window size is presented in this brief. An evaluation of the proposed ATIRF algorithm using MATLAB demonstrated better performance in terms of PSNR values compared to prior approaches. The performance of our algorithm is tested against varying noise densities and also against different images. The quantitative and qualitative results imply that the performance of the proposed ATIRF approach is better for different noise densities irrespective of the nature of the input image compared to prior arts.

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