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Removal of High Density Salt and Pepper Noise Through Modified Cascaded Filter

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Abstract: A modified cascaded filter for the restoration of gray scale and color images that are highly corrupted by salt and pepper noise is proposed in this paper. The proposed algorithm replaces the noisy pixel by trimmed median value when other pixel values, 0's and 255's are present in the selected window and when the entire pixel values are 0's and 255's then the noise pixel is replaced by mean value of all the elements present in the selected window. This modified cascaded filter shows better results than the Standard Median Filter (MF), Decision Based Algorithm (DBA), Modified Decision Based Algorithm (MDBA) and Progressive Switched Median Filter (PSMF). The modified cascaded filter is tested against different grayscale and color images and it gives better Peak Signal-to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF).

Key words: Progressive Switched Median Filter · Salt and Pepper noise · Trimmed median value

INTRODUCTION

In the transmission of images over channels, images are corrupted by salt and pepper noise, due to faulty communications [1, 2]. The objective of filtering is to remove the salt and pepper, so that the noise free image is fully recovered with minimum signal distortion [3]. Noise removal can be achieved, by using a number of existing linear filtering techniques which are popular because of their mathematical simplicity and the existence of the unifying linear system theory. A major class of linear filters minimizes the mean squared error (MSE) criterion and it provides optimum performance among all classes of filters if the noise is additive and Gaussian. However, these linear filtering techniques are not effective in removing non-Gaussian noise such as salt and pepper noise and it gives rise to non-linear signal processing techniques.

The best-known and most widely used non-linear digital filters, based on order statistics [4], are median filters. Median filters are known for their capability to remove impulse noise without damaging the edges. The main drawback of Standard Median filter (SMF) is that it is effective only for low noise densities. At high noise densities, standard median filters often exhibit blurring for large window sizes and insufficient noise suppression for small window sizes [5, 6].

The Alpha-Trimmed Mean Filter (ATMF) [7] is another type of non-linear filter, which, is also used to remove the salt and pepper noise in which the parameter "□", called the trimming factor, controls the number of values that are trimmed. It can be seen that as the value of the trimming factor "□" increases, the ability of the filter to remove salt and pepper noise is further increased. However, when the noise density is as high as 50% and above, there is insufficient noise removal and loss of image edge details. The reason for this loss in image edge details is due to the fact that the ATMF trims the extreme values even if they are not impulse values [4].

The decision based-median filter is a class of impulse rejecting filter it replaces only the corrupted pixels by some nonlinear filter and the uncorrupted pixels leave it unaltered [4]. The decision whether a pixel is corrupted or not is determined by the local image structure. Once uncorrupted pixels classified from the corrupted pixels and are used to train and predict the relationship between the center pixel and its neighbor pixel which can be used to replace the corrupted pixels. The drawback of this method is that it blurs the edges because it smoothes the variation between the center pixel and its neighboring pixels.

In order to overcome the above mentioned difficulties, a new two-stage cascaded filter is proposed in this paper which removes the noise as high as possible, without blurring and retains the fine edge details.

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The modified cascaded filter contains a new kind of decision-based median filter and un-symmetric trimmed mean filter which are connected in cascade. This decision based-median filter directly replaces the corrupted pixels only with a median value of its neighborhood pixels while the uncorrupted pixels are left unchanged. The Un-symmetric Trimmed Mean Filter (UTMF), as the name indicates, performs un-symmetric trimming of the impulse values and averages the remaining pixels. The purpose of using an un-symmetric trimmed mean filter is to remove only the impulse noise lying at the extreme ends, while the original pixel values are retained.

Algorithm

Decision-Based Median Filtering (DMF): The first stage of the modified cascaded filter is the decision-based median filter. In standard median filtering (SMF), each and every pixel value is replaced by the median of its neighborhood values. The decision-based median filter however makes a rough approximation of whether a pixel is corrupted or not. Then, the uncorrupted pixel values are retained and the corrupted pixels are replaced by the median value of their neighbors. Hence the output of DMF is superior to the SMF. The algorithm for DMF works as follows:

Step 1: A 2-D window 'S_{xy}' of size 3 x 3 is selected. The pixel to be processed is Z_{xy}.

Step 2: The pixel values in the window are sorted inascending order and Z_{min}, Z_{max}, Z_{med} are calculated.

Z_{min} - the minimum gray level value in S_{xy}
Z_{max} -the maximum gray level value in S_{xy}
Z_{med} – the median of gray levels in S_{xy}

Step 3: Calculate the differences b1 and b2 as given by
$b1 = Z_{xy} - Z_{min},$
$b2 = Z_{xy} - Z_{max}$

Step 4: If b1>0 and b2<0, the pixel being processed is un-corrupted and it is left unchanged. Else,the pixel is corrupted and it is replaced with the median value Z_{med}.

Move the window horizontally / vertically and repeat from step1 to step4. The above steps are repeated, until the processing is completed for the entire image. The output obtained is subjected to further processing.

Un-Symmetric Trimmed-Mean Filtering (UTMF): The idea behind a trimmed mean is to reject the most probable outliers. In the existing Alpha-Trimmed Mean Filtering (ATMF), the trimming is symmetric at either end. The number of values being trimmed depends upon the trimming factor "□". If the value of □=4, then "□/2" values are trimmed on both the ends and the remaining pixels are average [9-11]d. It is observed that higher the value of "□", greater is the noise suppression [9]. In ATMF, sometimes even un-corrupted pixel values are also trimmed. This eventually leads to loss of image detail and blurring of the image. In to overcome the above problem, an un-symmetric trimmed mean filtering method is proposed.

In UTMF, the trimming is un-symmetric i.e. the numbers of pixels trimmed at the two ends are not always equal. The UTMF checks whether the extreme values of the sorted array, obtained from the 3 x 3 window, are impulse values and trim only those impulse values. For example, if a 3 x 3 window does not have any impulse, the UTMF would not trim any values. On the contrary, the ATMF would trim values[10], irrespective of whether the 3 x 3 window has an impulse or not. This property of UTMF makes it more efficient in noise suppression than the existing ATMF [12]. The algorithm of UTMF is given below:

Step 1: A 2-D window 'S_{xy}' of size 3 x 3 is selected.

Step 2: The pixel values in the window are sorted in ascending order and stored in a 1-D array.

Step 3: If any pixel value in the array is either '0' or '255' (which is nothing but impulse noise), the corresponding pixel values are eliminated from the array. If there are no impulse values in the array, all the 9-elements are retained.

Step 4: The pixel being processed is replaced by the mean of the values in the 1-D array.

Move the window by one step and repeat from step 1 to step 4. The above steps are repeated, until the processing is completed for the entire image.

Cascaded Connection of DMF and UTMF: If The DMF is superior to the SMF because it removes only corrupted pixels. The disadvantage of DMF is that, the median pixel also be a noisy pixel value results in DMF fails to remove noise effectively at high density. The UTMF has better noise removing ability than the existing ATMF, owing to the fact that it uses an unsymmetrical trimming method to discard only the impulse values. The UTMF is used to remove the noise completely. At very high noise densities, around 80% there is blurring of the image.

Table 1: Comparison of PSNR values for various filtering methods

	PSNR (in decibels)						
			ATMF				
ND	A.S MF	DMF	α=2	α=4	α=6	II. UTMF	PA
10 %	33.06	36.52	29.03	31.32	32.44	32.65	32.41
20 %	28.78	31.45	24.94	28.91	30.65	32.35	32.18
30 %	23.60	25.30	21.80	25.86	28.44	31.90	31.88
40 %	18.81	20.52	19.38	22.70	25.91	31.36	31.45
50 %	15.27	16.69	17.23	19.54	22.88	30.64	31.05
60 %	12.30	13.47	15.55	17.15	19.73	29.58	30.51
70 %	10	10.86	14.24	14.72	16.63	28.50	29.74
80 %	8.08	8.74	13.02	12.71	13.48	26.39	28.54
90 %	6.64	6.95	11.97	11.14	10.73	23.3	26.03

Table 2: Comparison of IEF values for various filtering methods

	IEF						
			ATMF				
ND	A. SMF	DMF	α=2	α=4	α=6	III. UTMF	PA
10 %	57.92	128.77	22.75	39.97	50.04	52.13	50.54
20 %	43.09	79.06	17.94	44.67	66.65	98.24	94.24
30 %	19.74	29.23	13.06	33.16	59.92	132.84	131.82
40 %	8.80	12.80	9.89	21.38	44.85	156.10	160.30
50 %	4.79	6.65	7.53	12.99	27.62	166.07	181.93
60 %	2.92	3.81	6.16	8.90	16.12	155.75	192.80
70 %	2.00	2.44	5.30	5.97	9.21	141.68	198.51
80 %	1.47	1.71	4.57	4.29	5.10	99.23	163.98
90 %	1.18	1.27	4.04	3.34	3.05	59.11	100.05

The proposed cascaded algorithm uses a combination of both DMF and UTMF, to further improve the output obtained from the UTMF. The noisy image is first processed using the Decision-based median filter. The output of DMF is given as the input to the UTMF [13]. The cascaded connection is hence used to remove salt and pepper noise with a noise density as high as 90%. The cascaded connection yields the highest value of Peak Signal to Noise Ratio (PSNR) and Image Enhancement Factor (IEF) value as shown in Tables 1 and Table 2.

Simulation Results: The performance of the cascaded filter is studied at different levels of noise densities ranging from 10% to 90% The outputs are shown in Fig. 1.

The value of PSNR is calculated, using the formula:

$$\text{PSNR} = 10\log_{10}\left(\frac{255^2}{\left(1/_{M \times N}\right)\sum\left(r_{ij} - x_{ij}\right)^2}\right) \tag{1}$$

The IEF is calculated, using the formula:

$$IEF = \frac{\left(\sum_{i,j=1}^{256} s_{ij} - r_{ij}\right)^2}{\left(\sum_{i,j=1}^{256} s_{ij} - x_{ij}\right)^2} \tag{2}$$

where,

s – Original image
r – Corrupted image
x – Restored image
MxN – Size of image

In Fig. 1 the outputs of various filters like SMF (column 3), DMF (column 4), ATMF (column 5), UTMF (column 6) and modified cascaded filter(column 7) are shown. Column 1 represents the original image and column 2 represents image corrupted by impulse (salt & pepper) noise. From column 3 SMF can give a reasonable output only up to 50 %, the same thing holds good for DMF and ATMF. An acceptable quality of the image is obtained for 70% of noised image during the recovery

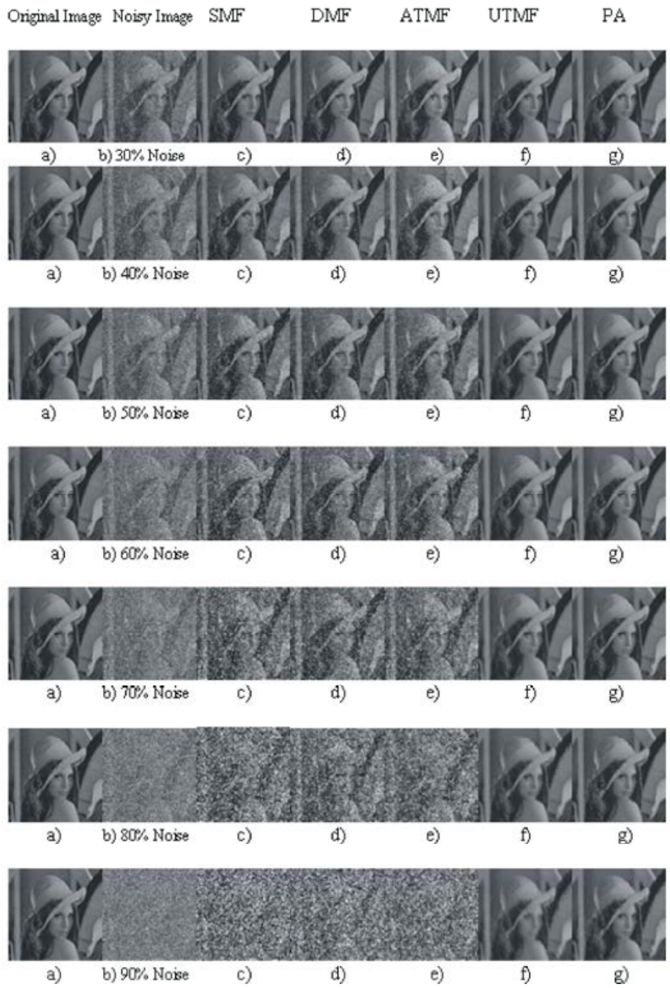


Fig. 1a): Original Image
Fig. 1b): Corrupted Image
Fig. 1c): Output of Standard Median Filter (SMF)
Fig. 1d): Output of Decision-based Median Filter (DMF)
Fig. 1e): Output of Alpha-Trimmed Mean Filter (ATMF) (with trimming factor □=4)
Fig. 1f): Output of Un-symmetric Trimmed Mean Filter (UTMF)
Fig. 1g): Output of Modified cascaded filter (PA)

Fig. 1: Image Filtering Results

using UTMF. However in case of modified cascaded filter there is an absolute recovery of 90% noised image which can be observed from the last row under proposed algorithm.

Fig. 2 is obtained from the values given in Table 1 for a given 10% noised image the maximum PSNR obtained is 36.52 when DMF is used. For 20% noised image the maximum PSNR is 32.35% under UTMF, the trend slowly changes towards modified cascaded filter in terms of increased PSNR as the noise densities increased up to 90% i.e., It can be observed the maximum PSNR is obtained using the modified cascaded filter when compared to other mentioned algorithm with noise density increased from 30% onwards.

Fig. 3 shows a plot of Image Enhancement Factor for various filtering algorithms. Similar to the trends of db obtained in Table 1 here also the IEF is more for the modified cascaded filter when the image is compared with SMF, DMF, ATMF and UTMF. However the general trend is that images are corrupted to the worst case and hence the modified cascaded filter will be very much apt in removing high density noised image.

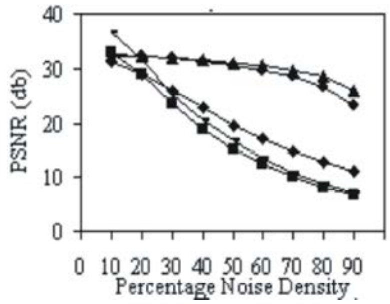


Fig. 2: PSNR Vs Noise density

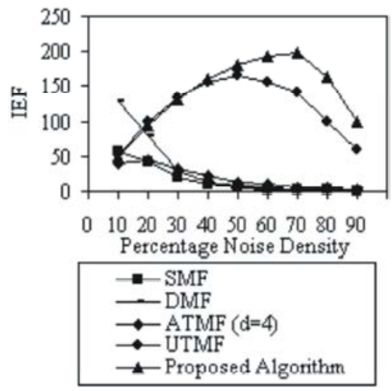


Fig. 3: IEF Vs Noise Density

Table 3: Comparison of PSNR and IEF values for Modified cascaded filter

	Camera man		Blood cell.tif		Eight.tif	
Noise Density (ND)	IEF	PSNR (in db)	II. IEF	PSNR (in dB)	III. IEF	PSNR (in dB)
10 %	15.42	26.97	33.79	30.66	36.67	30.00
20 %	39.38	26.65	63.71	30.35	67.81	29.74
30 %	41.38	26.50	82.77	29.72	101.13	29.54
40 %	53.52	26.36	97.90	29.25	124.30	29.27
50 %	61.30	25.94	98.91	28.31	143.01	28.86
60 %	66.66	25.54	97.91	27.47	156.75	28.48
70 %	65.70	25.09	82.04	26.06	164.05	28.03
80 %	59.05	23.74	53.69	23.59	142.27	26.78
90 %	40.06	21.55	25.57	19.90	87.51	24.17

Fig. 4 represents the outputs of various filters for different images (camera man, blood cell and eight. tif) are analyzed. It shows that the modified cascaded filter completely removes the noise even if the noise density is as high as possible.

The Table 3 shows the IEF and PSNR values for the modified cascaded filter for the above images. The PSNR value is well within the minimum permissible range (25 db)for all the above images till the noise density is 70%. Above 70% noise density the PSNR value is starts decreasing slowly thus the edges are blurred even if the noises are removed effectively.

Implementation for Video Sequence: The Block Diagram and algorthim for removing the noise from noisy image.

Algorithm (For Image)

The algorithm for MCF is as follows:

Step 1) A 2-D window “Sxy” of size 3x3 is selected.

Step 2) the pixel values in the window are sorted in ascending order and stored in a 1-D array.

Step 3) if the pixel value in the array is either '0' or ‘255’, The corresponding pixel values are trimmed (eliminated) and the median of remaining values is calculated.

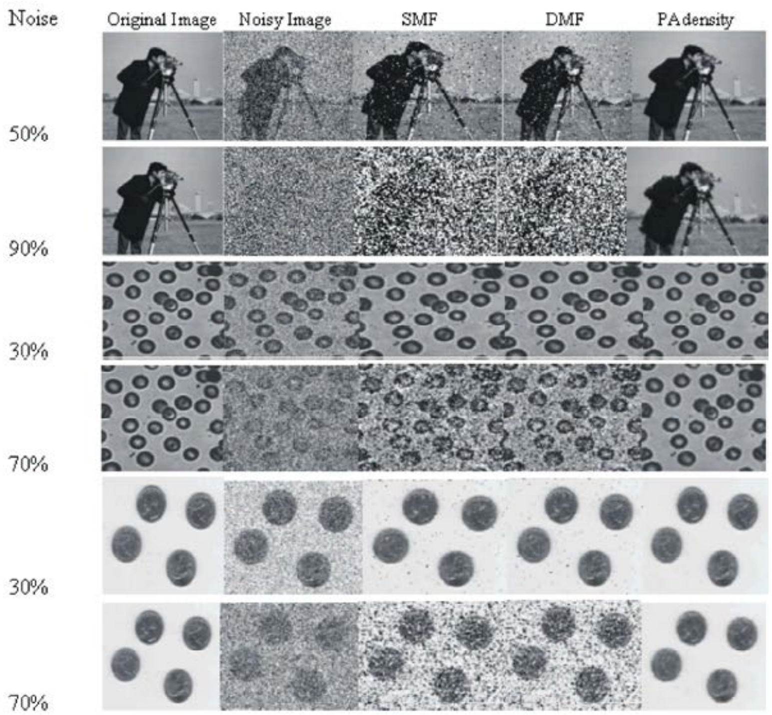
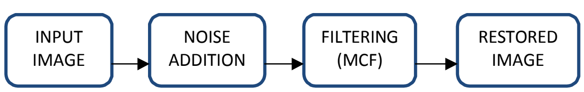


Fig. 4: Filtered output of Camera man, Blood cell and Eight. tif images

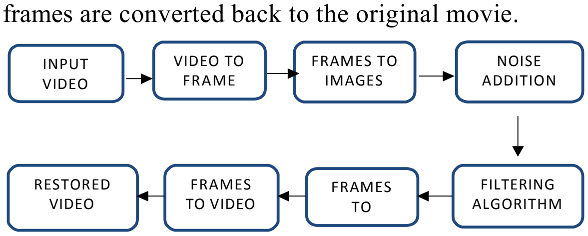
Step 4) the pixel being processed is replaced by the median value calculated. Move the window by one step and repeat from Step 2 to Step 4.

The above steps are repeated, until the processing is completed for entire image.



Block Diagramfor removing the noise from noisy image using MCF

Implementation for Video Sequence: The video sequence is first converted into frames and frames into images. Then MCF algorithm is applied to the images which are separated from frames. After the filtering process, the frames are converted back to the original movie.



Block Diagram for removing the noise from noisy video using MCF

Algorithm (For Video):

- Video to frames: The noisy video sequence containing Impulse noise is converted into avi format, which is an uncompressed format and frames are extracted from the Video.
- Frames to images: Frames are then converted to images for further processing.
- Filtering method: The noisy images are de noised using MCF algorithm.
- Frames to movie: After completing the entire process, the processed frames are finally converted back into original movie.

CONCLUSION

In this work, it can be observed that the performance of the proposed filter is superior to the existing filters. Even at very high noise densities (around 90%), the texture, details and edges are preserved effectively. The filtering method suggested can be further improved by using neural networks for further enhancing the outputs and also to remove other types of noise, such as random-valued impulse noise, mixed noise etc.

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REFERENCES

1. Srinivasan, E. and D. Ebenezer, November 2000. A New Class of Midpoint Type Non-linear Filters for Eliminating Short and Long Tailed Noise in Images, Third International Symposium on Wireless Personal Multimedia Communication, Bangkok, Thailand.
2. Pratt, W.K., 1978. Digital Image Processing (New York: Wiley).
3. Pitas, I. and A.N. Venetsanopoulous, 1990. Non-linear Digital Filter Principles and Applications, (Boston: Kluwer Academic publishers).
4. Astola, J. and P. Kuosmanen, 1997. Fundamentals of Non-Linear Digital Filtering, BocRaton, CRC.
5. Manikandan, S., O. Uma Maheswari, D. Ebenazer, July 2004. An Adaptive Recursive Weighted Median Filter with Improved Performance in Impulsive Noisy Environment, WSEAS Transactions on Electronics, 1(3).
6. Ho-Ming Lin, 1988. Median Filters with Adaptive Length, IEEE Transactions on Circuits and Systems, 35(6).
7. Huang, T.S., G.J. Yang and G.Y. Tang, 1995. Fast two dimensional Median Filtering algorithm, IEEE Transactions on Acoustics, Speech and Signal Processing, 1: 499-502.
8. Pok, G. Jyh-Charn Liu, Decision based median filter improved by predictions.
9. Jayalakshmi, V. and N.O. Gunasekar, 2013. Implementation of discrete PWM control scheme on Dynamic Voltage Restorer for the mitigation of voltage sag /swell, 2013 International Conference on Energy Efficient Technologies for Sustainability, ICEETS, pp: 1036-1040.
10. Uma Mageswaran, S. and N.O. Guna Sekhar, 2013. Reactive power contribution of multiple STATCOM using particle swarm optimization, International Journal of Engineering and Technology, 5(1): 122-126.
11. Arumugam, S. and S. Ramareddy, 2012. Simulation comparison of class D/ Class E inverter fed induction heating", Journal of Electrical Engineering, 12(2): 71-76.
12. Nagarajan, C. and M. Madheswaran, 2012. Experimental study and steady state stability analysis of CLL-T series parallel resonant converter with fuzzy controller using state space analysis, Iranian Journal of Electrical and Electronic Engineering, 8(3): 259-267.
13. Ramkumar Prabhu, M., V. Reji and A. Sivabalan, 2012. Improved radiation and bandwidth of triangular and star patch antenna, Research Journal of Applied Sciences, Engineering and Technology, 4(12): 1740-1748.