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Review of denoising algorithms

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Abstract: *The noise will affect an image from a variety of sources through various paths present in the nature, so the image restoration is needed. The main goal of image restoration tech. is the removal of noise from an image where the "original" image is perceptible. This paper presents an overview of filtering techniques, image noise models and a comparison of different filters (MF, UMF, DBMF, PSMF) for gray-scaled as well as colored images of different format at different noise variance through visually & also based on the calculations of mean square error, peak signal to noise ratio, image enhancement factor, mean absolute error. Thus the results show that the UMF filter preserved the features, information & as well provide smoothness by removing the FVIN from the image. Its performance is better than the other non-linear filters at very high noise variance.*

Keywords: *Image restoration, FVIN, Non linear filters, MAE, PSNR, IEF, MSE.*

Introduction

Digital images plays very momentous role in our daily scenario. These are used in satellite television, traffic monitoring & recognition, signature validation, computer resonance imaging & in region of research & tech.(such as geographical information systems and astronomy). Various types of noises & artifacts are introduced during the processing of images in the communication channel. De-noising the image is the most significant task than others in image processing. Its major goal is the removal of noise without excessive smoothing of fine details & preserving the edges of an image. Different types of de-noising techniques are used in the noise suppression and preserving actual image discontinuities depending on the noise model. A Color image stores 3-D data in it contains 3 components Red, Green and Blue each component is a considered as a 2D image like a gray scale image having two spatial co-ordinates. Zhou Wang & David Zhang proposed PSMF, to restore images corrupted by salt–pepper type impulse noise. The simulation results demonstrate that the proposed PSMF is better than traditional median-based filters because it provides the smoothness and also particularly effective for the cases where the images are very highly corrupted. Hassan.M.ElKamchouchi, Ahmed.E.Khalil, Samy H.Darwish[5] presents an overview of effective algorithms of UDBMF & DBMF in image restoration & simulation results demonstrate that the proposed filters are compared with no. of existing non-linear filters at different noise levels based on the calculations of MAE, MSE, PSNR, IEF. Sandeep Kaur1, Navdeep Singh2: proposed discussion on different noise models, different filters (linear & non-linear), Wavelet transform and simulate the results through different approaches of wavelet & several thresholding tech., also provide comparison through different parameters (SNR, MSE).

This paper has been organized in the following manner, Section (II) describes the meaning & types filtering technique, Section (III) contains image noise models, Section (IV) discuss the analysis of parameters, Section (V) presents simulation & the discussions of results, conclusions were presented in Section (VI). Finally, the references that used for completion of this work were included.

Section II: Filtering Techniques

Filters are used for image restoration by removal of undesirable components & suppressing the useful information in the signal. The designing of filters involves three basic steps: (1) the specification of the desired properties of the system, (2) the approximation of these specifications using a causal discrete time system, (3) the realization of the system using finite precision arithmetic. Filters are used because of their flexibility, cost effectiveness, programmability, reliability, etc. Basically there are two types of filter models 1) linear filters and 2) nonlinear filters model. linear filters processed the corrupted pixels in the image as much faster than the non-linear filters but the drawback is that they are not able to preserve the edges on the another side nonlinear filter models are preserve edges of the images in an efficient manner. So the detailed overview of the non-linear filters (MF, PSMF, DBMF, UMF) are presented below:

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A) Median Filter (MF):

The median filter is a robust non-linear filter which is used to remove the SPN (Salt-&-pepper noise) from the image. The basic concept of MF is to move through the image pixel-by-pixel and replacing each pixel value with the median value of its neighboring pixels in the selected window of order (W*W), where W is odd.

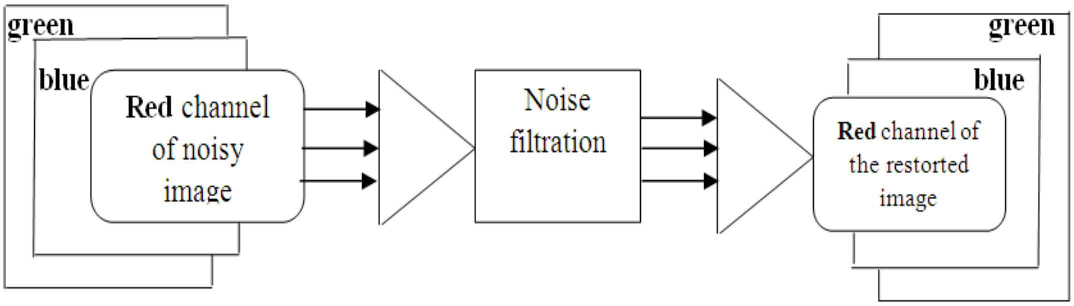
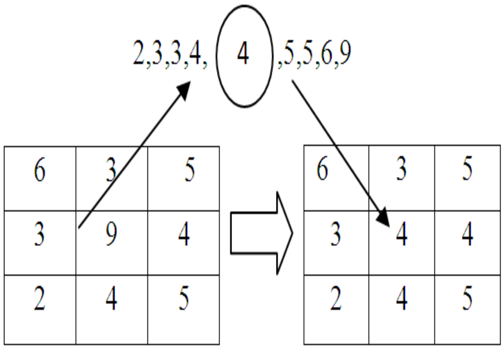


figure1: Process of image restoration

Basically, the median is calculated by sorting of all the pixels in numerical order in the selected window, then checks weather the selected window have odd number of entities or even. If there are odd number of entities then the middle value is the median value of the selected window & if even entities then the median value is calculated by the two middle entities. An example of 2-D median filter is shown below:



In the above example the selected window (W×W) where W=3, the centre pixel value (ie. = 9) is replaced by the median value (ie.= 4) of the same window. This filter is used as a smoother in different processing tech. (like image, signal, time series processing). The negative point of this filter is that every pixel in the selected window of the image is changed during noise filtration process. Its results are effective at low noise density.

Progressive Switched Media Filter (PSMF):

The process of filtration through this non-linear filter is done in two stages. First stage is Impulse detection through which two sequences (ie. binary & flag) are generated & second is Fine filtration which is applied progressively through several iterations.

(a) Impulse detection: The impulse detection is done through the steps which are given below:

Step1: Two images are generated while the process of impulse detection first one is the noised gray scale image denoted by (X) and second is binary Flag image and it is denoted by (F).

Step2: if the flag is equals to null ie. ‘0’then the processing pixel is called as non noisy pixel also called as noise free pixel & if the flag is ≠ 0 ie. F=1 the processing pixel is noisy pixel or the impulse is present.

Step3: Before starting the 1st iteration let us assume that F= [0] that mean all the pixels are good or we say noise free.

Step4: In each iteration for each pixel X(i, j) find the M (median value) of window m×m (where m is odd).

Step5: Here Th is threshold value: **If**{ | X(i,j)–M(i,j) |< Th} **Then** **{**F(i,j) = old (F(i, j))}; **Else** 1.

Step6: **If {** F(i, j) ≠ old [F(i, j)] **Then {** X(i,j) = M(i, j) } **Else** X(i, j) = X(i, j)

After completion of last iteration two images ie. X(i, j) & F(i, j) are obtained at the output end.

In which only F(i, j) is used for further filtering process.

(b) Fine Filtering: There are also two images gray scale image denoted by (Y) and binary Flag image denoted by (G) are generated during the process of filtration.

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Step 1: if the flag is equals to null ie. [G(i, j) = '0'] then the processing pixel is called as non-noisy pixel also called as noise free pixel. And if the flag indicates [G(i, j) ≠'0'] that mean flag is equals to 1 the processing pixel is noisy pixel or the impulse should be filtered.
Step 2: Here initially G(i, j) = F(i, j) means to say that G(i, j) is not blank.
Step 3: Find the M (median value) of window m×m (where m is odd). Her median value is calculated for all the pixels which is good that mean G(i, j)= 0.
Case (1): If the number of pixels of window m×m is odd, then: M = (n+1)/2
Case (2): If the number of pixels of window m×m is even then: M = [{(n/2)+(n+1/2)+1}/2]
Step 4: If { G(i, j) = 1 & M > 0 } **Then {** Y(i, j) =old M(i, j) } **Else** { Y(i, j) =old Y(i, j)} ;
Step 5: Once an impulse pixel is corrected, it is considered as a good pixel in the subsequent iterations.
If {Y(i, j) =old Y(i, j)} **Then {** G(i, j) =old G(i, j) }
If {Y(i, j) = old M(i, j)} **Then** { G(i, j) = 0 }
Step 6: The procedure stops after the last iteration when all of the noisy pixels have been corrected i.e. ∑ **G(i, j) = 0**
And hence we finally obtain the image **{Y(i, j) }** which is the restored output image through the PSMF. This filter performed well for fixed valued impulse noise but for random values the performance is abysmal. It also provides "smoothening" even at high noise-variance.

UMF:
The elements of the selected window are sorted in either increasing or decreasing order. If the processing pixel lies between 0 & 255 then the processing pixel is noise free & if the processing pixel is 0's or 255 then the pixel noisy. For removing the noise the noisy pixel value is replaced through median value of the remaining pixels in the selected window (W×W). it is used to remove the effect distortion. UMF is very effective to remove the effect of FVIN at very high noise-variance.
DBMF:
If the processing pixel value is in between max. & min. gray level then that pixel is noise-less & left unchanged. But if the processing pixel value takes the 0's or 255's && all surrounding pixels have same value in the selected window then that was noisy pixel & processed by the filtration part by replacing corrupted value with the mean value. Otherwise eliminate the 0's or 255's & noisy pixel value is changed with median value. DBMF is good for noise removal at high level of noise- variance but produces distortion in the output image.

Section III: Noise classification

Noise causes the random fluctuations in brightness & color information in the image due to the various conditions (like environmental conditions, camera quality, high energy spikes generates during transmission, etc.) which degrades the quality of an image. Generally, it is classified as:
Speckle Noise: Speckle noise is a type of multiplicative noise & it is signal dependent. This noise gives a 'magnified' view of the image ie. means when speckle noise effects the high intensity pixels values then the large amount of random variation is produced in the image & when this effects the low intensity pixels values then the amount of random variation is low as compared with brighter area. Gaussian noise: It is also called as additive noise basically used in information theory & uniformly distributed over the image. Its effects is maximum in the blue channel then red or green channels reason being the blue color needed more amplification than others of the colored image. Salt-&-Pepper Noise (SPN): this is a type of impulse noise & caused due to errors in data transmission through the communication channel. Its probability is always less than 0.1. Usually the value of Salt noise is '255' & Pepper noise '0'.

Section IV: Parameters Analysis

To evaluate the comparative performance of different filters for removals of salt-&-pepper noise different standard feat indices are used which are defined as follows:
1) Mean-Square-Error (MSE): It can be expressed by summation of the squared difference between the original image & the restored image and dividing this by the total pixel count. It is evaluated pixel-by- pixel value in the selected window & defined as:
MSE = 1/ (W×W) × [Sum{Sum{(X-b).^2}}]

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2) Peak-Signal-to-Noise-Ratio (PSNR): It is defined as the ratio between the square of maximum pixel value & the mean square error of an image. PSNR is measured in decibel (dB) & if the PSNR is high in the output image then the quality of image is considered being good & expressed as: **PSNR** = $10*\log10 \{(255)^2 / \text{MSE}\}$

3) Mean Absolute Error (MAE): it is defined as the measurement of how much the restored image are close to the original image. Its expression is given below:

MAE = $1/ (W\times W) \times [\text{Sum}\{\text{Sum}\{\text{abs}(b-X)\}\}]$

4) Image Enhancement Factor (IEF): It is defined as measurement of the quality of an image & expressed as: **IEF** = $\text{Sum}\{\text{Sum}(a-X)^2\} / \text{Sum}\{\text{Sum}(b-X)^2\}$

Here 'X' is the original image, 'a' is the noisy image, 'b' is the resorted image & 'W×W' is the pixel count of the image.

Section V: Simulation Results & Discussion

To validate the de-noising methodologies an image 'obama' of size 256×256 is considered. The performance of the proposed algorithm is evaluated with comparable study for various standard filters. The figure (a), (b), (c), (d), (e) & (f) shows the original image, noisy image & de-noised image obtained using MF, DBMF, PSMF, UMF

Fig.(a) original Image

Fig.(b) Noisy image (at noise_var.= 0.7)

Fig.(c) Denoised image (by using MF)

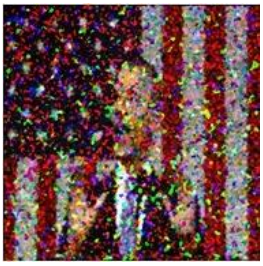

Fig.(d) Denoised image (by using PSMF)

Fig.(e) Denoised image (by using DBMF)

Fig.(f) Denoised image (by using UMF)

Table1: comparison of MSE for diff. filters

MSE				
VAR.	**MF**	**DBMF**	**UMF**	**PSMF**
0.1	**22.5989**	27.9441	29.7710	81.6732
0.2	99.8608	**43.1905**	53.6363	152.7104
0.3	112.1668	84.3111	**77.7275**	226.9531
0.4	138.3202	143.3930	**122.5887**	474.8783
0.5	153.2901	213.4537	**143.8010**	954.6797
0.7	551.1191	472.7008	**407.3163**	7.7807e+03

Table2: comparison of PSNR for diff. filters

PSNR				
VAR.	MF	DBMF	UMF	PSMF
0.1	**53.9830**	33.8262	33.1105	28.5866
0.2	40.4513	**45.8725**	40.8362	25.4852
0.3	37.0590	28.8720	**37.8506**	22.7203
0.4	32.0035	26.5655	**35.2463**	20.5646
0.5	15.2765	24.8378	**30.4873**	18.0739
0.7	11.0450	21.3849	**23.3688**	9.1237

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Table3: comparison of MAE for diff. filters

MAE				
VAR.	MF	DBMF	UMF	PSMF
0.1	**0.3466**	0.9040	0.8977	1.8745
0.2	**0.7983**	1.7084	1.5843	3.1380
0.3	5.5079	**2.0205**	2.4021	4.9226
0.4	2.9493	3.8389	**2.3071**	7.2720
0.5	5.5990	5.2478	**4.4969**	11.1205
0.7	16.3448	9.1537	**8.6033**	51.2786

Table4: comparison of IEF for diff. filters

IEF				
VAR.	MF	DBMF	UMF	PSMF
0.1	4.4307	**85.9715**	82.7563	24.1571
0.2	4.0871	**82.1311**	81.0166	23.7923
0.3	3.7559	**78.5623**	76.8290	18.8122
0.4	3.1969	60.7708	**71.4667**	15.1700
0.5	2.5861	51.0661	**59.9651**	10.6466
0.7	1.7403	32.5325	**35.8182**	1.9005

Table 1- 4 gives the objective comparison of these filters for different values of noise variance. The results of UMF gives lower (MSE, MAE) & higher (PSNR, IEF) and its performance are superior then other filters at high noise-variance.

Section VII: Conclusion

In this work, different filters have been used as a tool for removing low and high density salt-&-pepper noise with edge preservation in digital images. Through visual inspection of colored images; for low noise variance up to 0.3, existing filters performs well to remove the noise. For noise variance above 0.4 & 0.5, only DBMF and UMF gives better results. At high noise-variance (0.7 onwards), DBMF produces streaking effect in the image. Both visual and quantitative results are demonstrated that the UMF filter remove the impulse noise very effectively in images at high noise variance.

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