Image Denoising By Multi-Pass Median Filter Based on Decision Based Expanded Window

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Abstract

In this paper we proposed a new multi-pass median filterwhich is based on decision based expanded window to remove the salt and pepper noise. Proposed filter works on noisy pixel by using a window around that noisy pixel without affecting noise free pixels. At low noise density noisy pixel is replaced with trimmed median value of the window. Window is expanded if it contains three forth noisy pixels of total pixels of window to find more noise free pixels, in order to prefer median filter instead of mean filter at high noise density. We also preferred multiple scanning of same image, that increases the probability of noise free pixel at high noise density and median filters are in use which are effective and provide better results.

Keywords

Median Filters, Decision Based ExpandedWindow, Multiple Pass Filter.

I. Introduction

Impulse noise in the image is introduced during image acquisition stage or present due to bit error in transmission. Impulse noise is of two types: salt and pepper noise and random valued noise [1]. An image is said to be corrupted with salt and pepper noise when a corrupted pixel takes maximum value (255) or minimum value (0) of gray level. Many Non-Linear filters have been proposed for restoration of images corrupted with salt and pepper noise. Out of them a class of widely used non-linear filter is median filter for salt and pepper noise [3] because of its good de-noising capability and computational efficiency. For a noisy image I (i, j) corrupted by salt and pepper noise median filtering operation can be mathematically written as [8]:

$K(i, j) = \text{median}\ \{I(i, j), (i, j) € W\}$

Where K (i,j) is restored image and W represents a spatial window around a noisy pixel, centered on location (i, j).

II. Related Work

It has been noticed that Standard Median Filter (SMF) is a reliable method to remove salt and pepper noise without damaging edge details. However, this filter cause blurring of edge details at high noise density that is these filters only applicable for low noise density images is its major drawback [11,16].

Most of the median filters operate uniformly across the image thereby try to modify both noisy and noise free pixels [12]. But the filtering action should be carried out only on noisy pixels without affecting noise free pixels. So, a noise detection process should be carried out to distinguish between noisy and noise free pixels[6]. Another filter Adaptive Median Filter (AMF) in which firstly noisy pixel is detected than filtering action is performed on it without affecting noise free pixels [13]. In these filter noisy pixel is replaced by the median value of the window which is selected around the noisy pixel. Hence, AMF performs effective at low noise density but window dimension has to be increased at high noise density which may leads to blurring of image details [14]. In Switching Median filters decisions are made on the basis of predefined threshold value. But disadvantage of this method is that to identify a robust decision is difficult. These filters will also not take in account the local features of the image means which edges and details may not be recovered.

A Decision Based Algorithm (DBA) [3] is proposed to overcome above drawback. In DBA filtering is performed using a fixed window dimension of size 3x3. If the pixel is noisy means its value is 0 or 255, it is processed otherwise left unchanged. The noisy pixel is replaced with the median value of the window. But at high noise density the median value of the window may be 255 or 0 because probability of noisy pixels is more at high noise density. So, this filer uses neighboring pixels for replacement, but repeated replacement with neighboring pixels produce streaking effect. In order to avoid this drawback Decision Based Unsymmetrical Trimmed Median Filter (DBUTMF) is proposed [7]. This filter unsymmetrically trims both 0's and 255's from the selected window, than noisy pixel is replaced with the median value of the pixels in the window which are left after trimming. But at high noise density when all the pixels in the window are 0 and 255 than median value cannot be obtained. So, this algorithm does not provide better results at noise density above the 70%. The Proposed Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) overcomes this drawback [5]. This filter replaces the noisy pixel with the mean value of the window at high noise density [9]. But this replacement produce dark patches in the restored image.

To overcome the drawback of above filter Decision Based Coupled Widow Median Filter (DBCWMF) has been proposed[4]. This filter uses a coupled window of increasing size in order to find noise free pixels. In small size (3x3) window the probability that entire pixels are noisy is high at high noise density, but if window size is increased (5x5) at same noise density than probability get reduce. So in this filter size of window is increased up to 7x7, but if still entire pixels in the window are noisy than this replacement is done with the mean value which may again sometimes leads to dark patches at high noise density [10].

III. Proposed Algorithm

In this paper we proposed a powerful three pass filter which combines the method used in coupled window median filters but set of conditions are different and multiple scanning is enrolled in order to increase the probability of noise-free pixels at high noise density. The proposed algorithm Decision Based Expanded Window Multiple Pass Median Filter (DBEWMPMF) has three passing and each pass work in two steps. In First step noise detection process is carried out using impulse model. The main motive of this process to detect the noisy pixels, if pixel is noisy means its intensity value is either 0 or 255 than Second step is carried out otherwise it is left unaltered. In Second step filtering is applied on noisy pixels in three stages. If the pixel is noisy a window of size 3x3 is selected considering noisy pixel as the central pixel. After this window is checked for a condition which is whether it contains noisy pixels three forth of total noisy pixels of the window or not.

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At First Pass

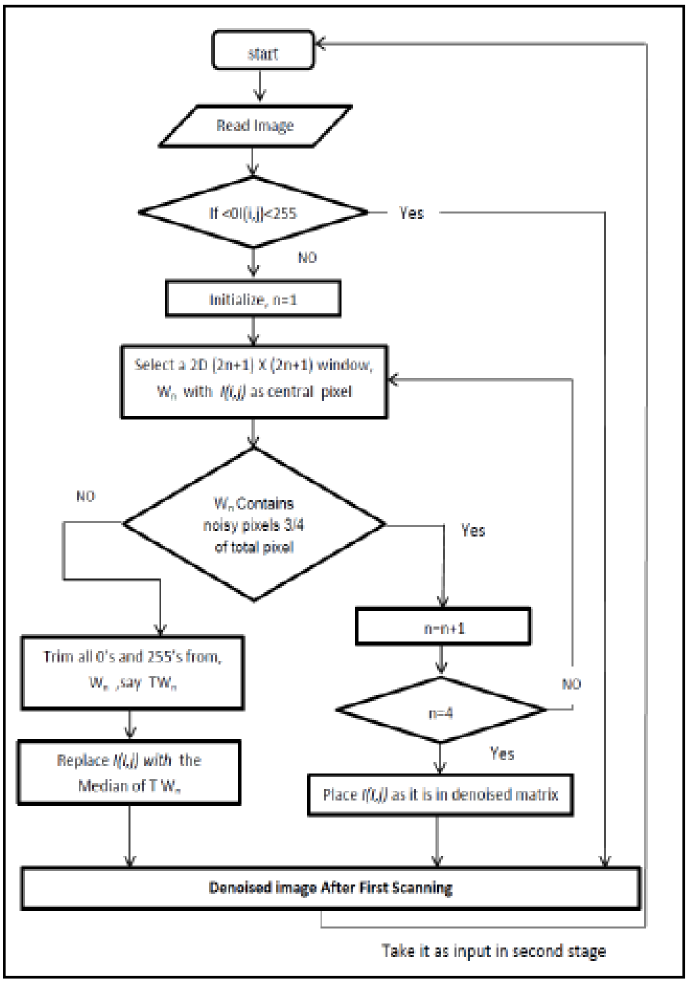

Fig. 1: Flow Chart of Proposed Algorithm at First & Second Pass

If the noisy pixels are less or condition is false than unsymmetrical trimmed median filters are used that trims all the noisy pixels (0 and 255) and replace the central noisy pixel with the median value of the window. But if the condition becomes true that is window contains three forth or more noisy pixels of the total pixels in window than window is expanded (5x5). This filter expands the window up to 7x7 but if still condition is true than it performs different action at 3 different passes:

At First Pass

If above condition is true central pixel is placed as it is in the de-noised image. Whole process is carried out for each pixel in the image. First Pass generates a de-noised image this is the input for Second Pass as shown in figure 1.

At Second Pass

If above condition is true Central pixel is again placed as it is in the de-noised image. Whole process is carried out for each pixel in the image. Second pass generates a de-noised image again this is the input for Third pass.

At Third Pass

Central pixel is replaced by the mean value of the window if condition is true. This stage will also generate a de-noised image, which is the final output of proposed algorithm as shown in fig. 2.

Algorithm

Step 1 Window Selection: Select a 2-D window W_n of size (2n+1) x (2n+1) assume I (i,j) is central pixel of W_n expanded window(let n==1)

Step 2 Noise Pixel Detection: If I(i,j) = 0 or 255 then it is noisy pixel and should be processed.If 0<I(i,j)<255 then I(i,j) is a noise free pixel so it should be left as it is. It can be written as:

$$K(i,j) = \begin{cases} \text{noise free pixel if } 0 < I(i,j) < 255 \\ \text{noisy pixel if } I(i,j) = 0 \text{ or } 255 \end{cases}$$

At Third Pass

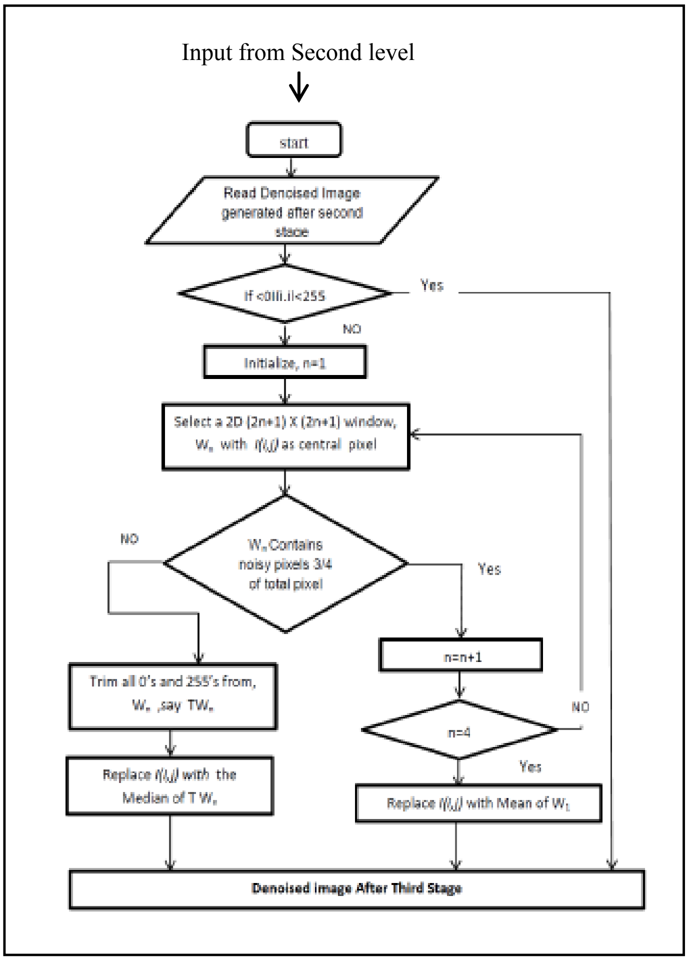

Fig. 2: Flow Chart of Proposed Algorithm at Third Pass

Step 3 Filtering Operation: If a pixel is noisy (0 or 255) then DBEWMPMF is used window (selected in Step 1)

Case 1: if window Wncontains noisy pixels >¾ of total pixels in the window then n is incremented by 1.

n=n+1

go to step1

Case 2: if window $W_n$contains noisy pixels< ¾ of total pixels in the window than unsymmetrical trimming is followed that trim all the 0 and 255 from window and replace noisy pixel with median of window TW_n(window generated after trimming)

K(i,j)= {median (TW_n)}

Where K(i,j) is a restored value

Step 4: The window size can be increased up to n<5 for finding noise free pixels because computational complexity of algorithm increase beyond n>5. When n=4 window is of size 7 x7 replacement of pixel as different passes:

At First and Second Pass
K(i,j)=I(i,j)

At Third Pass
K(i,j)={mean (W_1)}

Second pass is applied on the image generated at the end of first pass. As it is Third Pass is applied on the image generated after Second pass.

Step 5: Repeat step 1-4 in for loop until all the pixels of the image are processed at each pass.

For a RGB image the above mentioned algorithm need to separately operate on each color channel. After de-noising operation separate channels can be concatenate to have a de-noised color image.

IV. Simulation Results

We used Matlab R2010 for simulation of the proposed algorithm. Performance of the proposed algorithm has been evaluated on different gray scale and colored images. The noise density is varied from 10% to 90%. De-noising performance is measured by MSE(Mean Square Error) [9], BER (Bit Error Rate), PSNR (Peak Signal to Noise Ratio) [2], SSIM (Structural Similarity Index Measure), IQI(Image Quality Index), IEF(Image Enhancement Factor).

$$MSE = \frac{1}{AB}\sum_{i=1}^{A}\sum_{j=1}^{B}(i(i,j)-k(i,j))^2 \quad (1)$$

$$BER = P/(A*B) \quad (2)$$

Table 1 Simulation Results for Lena Image(512 x512)

Filter Type	Attributes	Noise Density %				
		10	30	50	70	90
Proposed Median Filer	MSE	0.496	1.741	3.265	5.364	25.558
	BER	0.019	0.021	0.023	0.024	0.0294
	PSNR	51.16	45.72	42.99	40.83	34.055
	SSIM	0.996	0.985	0.968	0.933	0.8289
	IEF	905.4	761.9	666.6	560.3	193.84
	IQI	0.971	0.902	0.812	0.684	0.5334

Fig. 3: Simulation of Lena At 30% Noise density

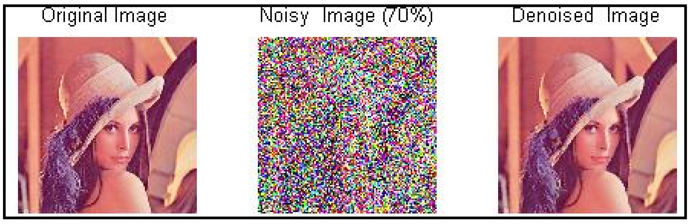

Fig. 4: Simulation of Lena At 70% Noise density

$$PSNR = 10log_{10}\frac{Q*Q}{MSE} \quad (3)$$

$$SSIM = \frac{(2\mu_I\mu_K+c1)(2\sigma_{IK}+c2)}{(\mu_I^2+\mu_K^2+c1)(\sigma_I^2+\sigma_K^2+c2)} \quad (4)$$

IQI= Corr (I,K) x Lum (I,K) x Cont (I,K) (5)

$$\text{Corr (I,K)} = \frac{\sigma_{IK}}{\sigma_I\sigma_K}$$

$$\text{Lum (I,K)} = \frac{2\mu_I\mu_K}{\mu_I^2+\mu_K^2}$$

$$\text{Cont (I,K)} = \frac{2\sigma_I\sigma_K}{\sigma_I^2+\sigma_K^2}$$

σ_I^2 the variance of I,σ_K^2

$$IEF = \frac{\sum_{i=1}^{A}\sum_{j=1}^{B}[X(i,j)-I(i,j)]^2}{\sum_{i=1}^{A}\sum_{j=1}^{B}[K(i,j)-I(i,j)]^2} \quad (6)$$

where I (i, j), X(i, j), and K(i, j) represent original, noisy, and restored image of dimension A×B and P is the count number whose initial value is zero and it increments by one if there is any bit difference between Original and restored image. Q denotes the peak signal value of the cover image which is equal to 255 for 8 bit images. I original image, K restored image with μ_I the average of I, μ_K the average of K, C_1 and C_2 being the constants and σ_I^2 the variance of I,σ_K^2 the variance of K.

Table 2 Simulation Results for Baboon (512 X 512)

Filter Type	Attributes	Noise Density %				
		10	30	50	70	90
Proposed Medain Filer	MSE	1.919	5.836	10.09	15.31	24.62
	BER	0.021	0.024	0.026	0.027	0.029
	PSNR	45.29	40.46	38.08	36.27	33.41
	SSIM	0.999	0.959	0.908	0.807	0.293
	IEF	220.3	215.8	207.8	191.9	129.3
	IQI	0.905	0.901	0.803	0.684	0.174

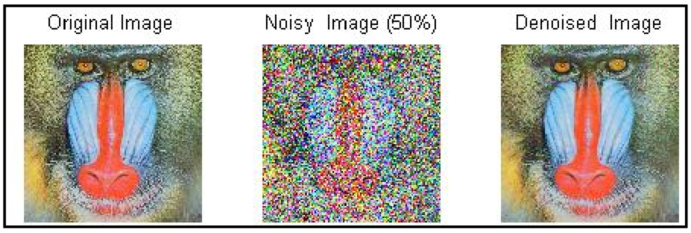

Fig. 5: Simulation of BamboonAt 50% Noise density

Proposed Algorithm gives 51.16 PSNR at 10% and 34.10 at 90% shows better results and also other parameters shows good results over [4].

Graphically representation of metrics MSE, BER, PSNR, SSIM, IQI, IEF for Lena colored image of size 512 x 512 shows better performance of proposed algorithm compares to existing one algorithms [4].

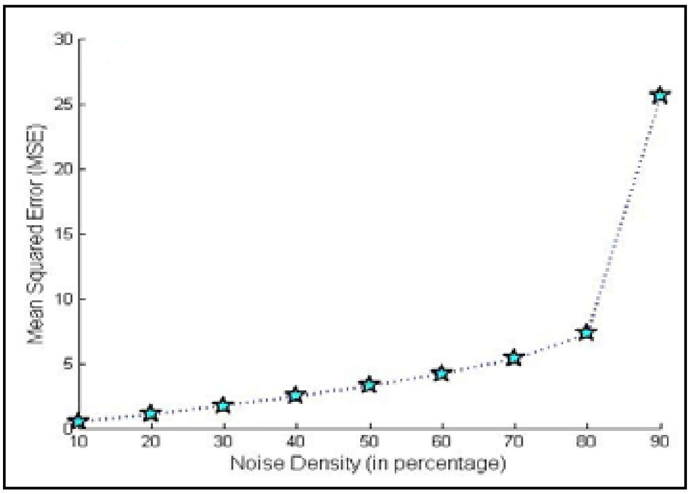

Fig. 6: Graph of MSE

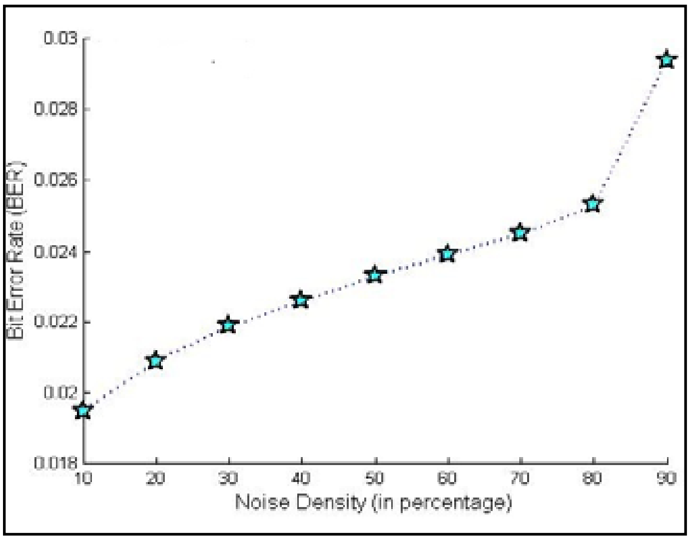

Fig. 7: Graph of BER

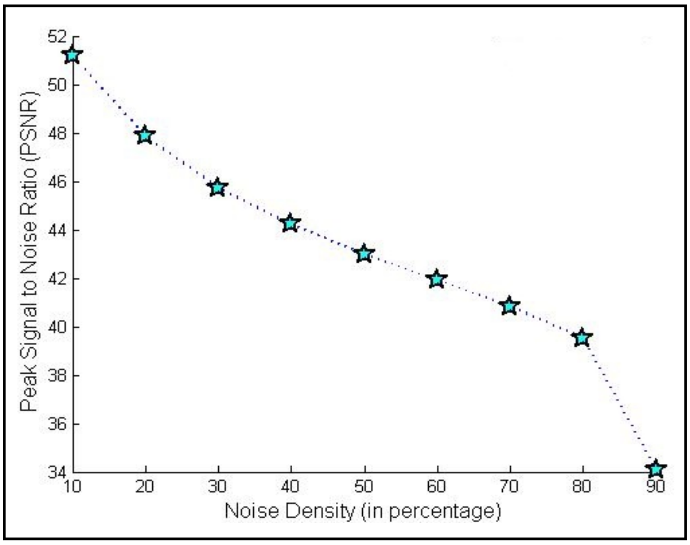

Fig. 8: Graph of PSNR

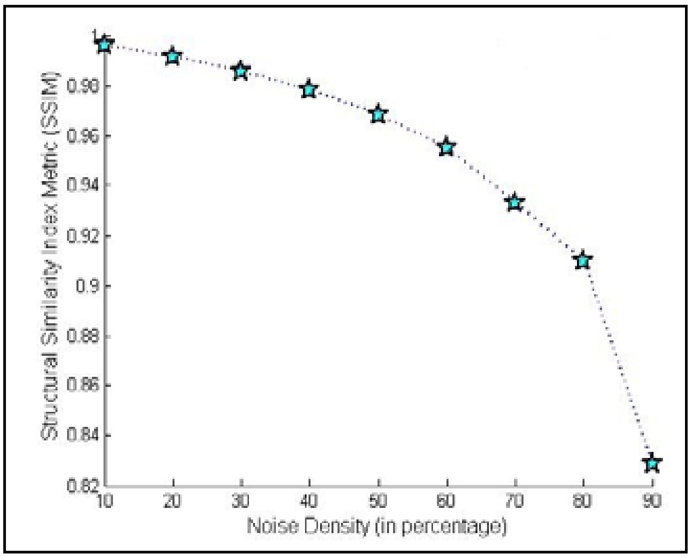

Fig. 9: Graph of SSIM

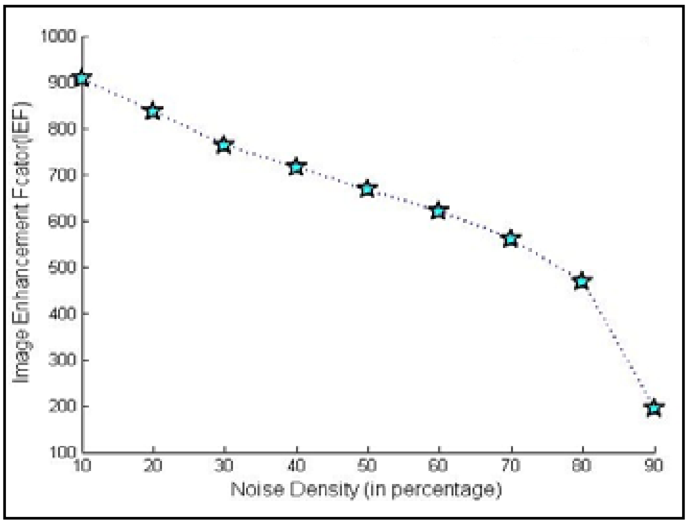

Fig. 10: Graph of IEF

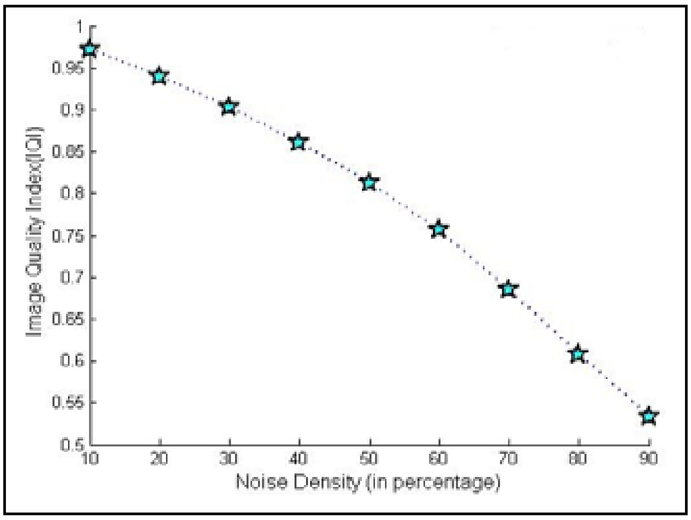

Fig. 11: Graph of IQI

V. Conclusion

In this paper an efficient decision based expanded window multi-pass median filter to restore an image corrupted with high density salt and pepper noise is proposed. DBEWMPMF with multiple pass Filter consist of three stages. This algorithm operates only on noisy pixels and gives better result as low noise density as well as high noise density. It has been found that proposed algorithm provides better results in terms of MSE, BER, PSNR, SSIM,IQI,IEF.

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