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Image Noise Reduction using Median Filter and Avoid Biased Values: MF-ABV

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ABSTRACT

One of the most important literature issues in the image processing is image filtering (image denoising or noise removal). Several different techniques and algorithms were developed in order to remove or minimize the noise into the digital images, and each of them has pros and cons. The digital image could be prone to several noise types through acquisition or even during the transmission. The noise types could be classified into: salt & pepper, Gaussian, and speckle; and each noise type could be minimized or removed by specific filter type. This paper presents a new filtering algorithm which helps in minimizing or removing the Salt and Pepper noise. It could be considered as an enhanced version the standard median filter. The proposed algorithm works typically as the classical one except it avoids the biased values under the used window (3X3 for example) that moves over the image's pixels in order to do the filtering process. It is called Median Filter and Avoid Biased Values: MF-ABV. The experiments results showed the superiority of MF-ABV over the standard median filter depending on the objective quality measure such as the mean square error (MSE).

Key words: Median Filer, Image Processing, Salt-&-Pepper Noise, Filtering Algorithms, MSE.

INTRODUCTION

Quality and clarity of image become very important for people, especially in recent years, Noise can change the quality of the image due to bit errors in transmission, formation, storage or introduced during the signal acquisition stage, Noise usually makes difficult to know what a completely original image is? (Esakkirajan et al., 2011).

Erroneous memory locations, transmission, and malfunctioning pixels could cause some impacts of bit errors such as Salt and pepper noise (Bar et al., 2005). This type of noise can harm a huge number of pixels of the original image. A standard median filter (Toh & Ashidi, 2010) and other novel techniques such as (Otair et al., 2015) reduce a salt-and-pepper noise by windowing the noised image.

Salt-and-pepper is the kind of noise, it's one of the significant Impulse noises in images processing. A Lot of methods proposed to reduce the salt-and-pepper noise (Toh & Ashidi, 2010). The median filter is one the most popular a non-linear filter that achieved great success to manipulate and removing impulse noise on images without affecting the shape and characteristics of the image (Fahmy et al., 2005). Salt-and-Pepper noise is reflected as white and black pixels on the corrupted image, and so, the noisy pixel intensity will be either 0 or 255. The main contribution is this effort is to exclude these pixels before applying the median filter steps.

It's known the standard median operator ranks the intensities of the pixels inside every 3X3 block in the image and substitutes the center pixel by the median of the nine block elements (Pei-Eng & Kai-Kuang, 2006). This paper presents an enhanced version of the standard median filter which enhances the quality of the gray scale images by reducing or minimizing the salt-and-pepper noise.

THE PROPOSED SOLUTION (MEDIAN FILTER AND AVOID BIASED VALUES- MF-ABV)

The proposed filter removes the salt-and-pepper noise by enhancing the standard median filter. It processes each pixel in the corrupted image by defining a mask (window) of size 3x3 pixels that sorted in an ascending order. The additional step here is to avoid or eliminate all the noisy pixels with biased intensity values such as 0 and 255 before selecting the median value. MF-ABV steps will be implemented as follow:

1. Place a window over pixels (3X3 window).
2. Sort the pixels value in an ascending order
3. Avoid/Ignore/Discard the biased values. In other words, ignore the pixels with: 0 and 255 values
4. Find the median from the remaining pixel values (If the number of the remaining values are even then the median will be (N/2)+1 (where n is the number of the remaining values)

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5. The median value will be the new value in the filtered image in the corresponding element of the center pixel in the current window.
6. Repeat the above steps for all image pixels.

The proposed filter algorithm is so simple and it was implemented using MatLab commands, as follows:

```
I = imread ('cameraman.jpg');
J = imnoise (I, 'salt & pepper', 0.04);
F = medfilt2 (J);
K = J;
M = J;
[A, B] = size (K);
 for row= 2:A-1
 for col= 2:B-1
      Nbor = [J(row-1, col-1),J(row-1, col),J(row-1, col+1),
      J(row, col-1),J(row, col),J(row, col+1),
      J(row+1, col-1),J(row+1, col),J(row+1, col+1)];
  SNbor = sort (Nbor);
  LEliminate = 0;
  REliminate = 0;
     for pass = 1:9
         if SNbor(pass)== 0
       LEliminate = LEliminate + 1;
     end;
     if SNbor(9 - pass + 1)== 255
     REliminate = REliminate + 1;
  end;
  end;
K(row,col) = SNbor(5);
Mean = ((LEliminate+1)+(9-REliminate))/2;
M(row,col) = SNbor(round(Mean));
end;
end;
subplot (1,3,1); imshow (J); title('Salt-and-Pepper Nosie - 
4%');
subplot (1,3,2); imshow (K); title('Normal Median');
subplot (1,3,3); imshow (M); title(MF-ABV Filter');
```

HOW THE PROPOSED ALGORITHM DOES WORK?

In order to explain how the proposed algorithm does works, the following two examples will be used:

Example 1:

To express the main idea of the proposed algorithm, consider the following 3X3 block that taken from noisy image.

$$\begin{Bmatrix} 70 & 0 & 0 \\ 75 & 0 & 0 \\ 0 & 255 & 80 \end{Bmatrix}$$

Figure 1: A block 3x3 with Salt-and-Pepper Noise

The sorted 1-D array of the above matrix is [0 0 0 0 0 70 75 80 255]. In the built-in median function, the median value is 0 which is a noisy pixel. However, in the proposed filter all the “0” and “255” values will be discarded or eliminated yielding the new 1-D array as [70 75 80]. Therefore, the new median value is now 75, then remove the noise at the center pixel of the block by replacing it by new median value which is 75. While in the standard median filter the median of the nine values is 0. So, the black spot (pepper noise) will remain at the center of the block.

Example 2:

In order to proof the efficiency, validity, and superiority of the proposed filter over the classical median filter, consider the following figure which shows that the center of the original block (at left block) is changed from 125 to the white spot 255 as the new intensity value (at right block).

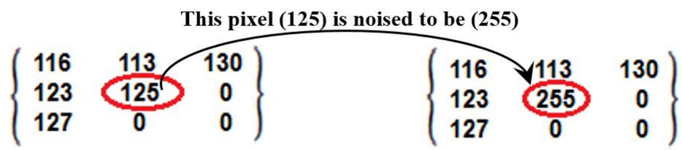

Figure 2: The original block (at left), the noisy block (at right)

If the noisy block is filtered using the standard median filter, then the nine values at the right (noisy) block will be sorted in ascending order as follows:

0, 0, 0, 113, 116, 123, 127, 130, 255

The median value of these sorted values is 116. So, the 255 will be replaced by 116 and the white spot will be manipulated. However, the original value was 125. So, the mean square error (MSE) for this pixel will be computed as follows:

$$MSE = (125-116)^2 = 81$$

If the noisy block is treated by the proposed filter, then the biased values such 0 and 255 will be discarded. After that, the remaining values will be sorted in ascending order as follows:

113, 116, 123, 127, 130

The median of the remaining values is 123. So, the 255 will be replaced by 123 and the white spot will be deleted. It can be noticed the deviation between the original value of the pixel and the new median (restored) value is very tiny. The MSE of the noisy pixel using the proposed filter will be as follows:

$$MSE = (125-123)^2 = 4$$

EXPERIMENTS AND RESULTS

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The MF-ABV and standard Median Filter algorithms have been experimented with several gray-scale images that have different dimensions. Different Salt and Pepper noise levels have been added to the experimented images as follow: 3%, 4%, and 5% respectively. The mean square error (MSE) was used as evaluation measure after the noises were minimized by the two algorithms, as follows:

$$MSE = \frac{1}{XY}\sum_{i=1}^{X}\sum_{j=1}^{Y}(f(x,y) - g(x,y))^2$$

Where g and f are the output and input images respectively. X and Y are the dimensions of the images (X is the number of rows, and Y is the number of columns). When the value of MSE is lower, then the quality of image will be better.

Seven standard gray scale images (Lena, Cameraman, Babon, House, Mosque, Barbara, and Boat) are prepared as test set images. These images have different sizes (or dimensions) and types. The selection of these images came because they are the mostly tested images in image processing research area. The Matlab built-in function imnoise is used to degrade the test set. The images are then reconstructed/denoise using the two filters: Standard Median filter and MF-ABV. These algorithms were tested and implemented overall the test set images using Matlab R2010a.

Figure 3 shows the results of denoising process using 3X3 mask using the Standard Median Filter and MF-ABV. The percentage of added noise to Cameraman image was 4%. It can be noticed that the quality of the filtered image using MF-ABV is better with preserving the image details and the sharpening of the edges. Visually, the processed images appear with little black and white pixels compared with the default Median filter when using Mask (window) of size 3x3 on corrupted images but when using Mask (window) of size 5x5 on images the processed images appear with much black and white pixels compared with the default Median filter.

(a) (b) (c)

Figure 3: Comparative of Image Quality using 3X3 Mask (a) Image with 4% Noise (b) Filtered Image by Standard Median (c) Filtered Image by MF-ABV.

Table 1 shows the MSE values produced by the standard median and MF-ABV at 3% noise level. In addition, it shows that enhancement achieved by MF-ABV. Generally, it is noticed that all the MSE values produced by MF-ABV are less than the MSE values by the standard median, which means that the quality of the reconstructed images by MF-ABV are better with all experimented images. The columns in table 1 as follow: Image Name, MSE by Standard Median, MSE by MF-ABV, and the achieved enhancement by MF-ABV, respectively. The results showed that the enhancement percentage achieved by MF-ABV over the standard median. These percentages are calculated using the following formula:

$$\text{Enhancement by MF-ABV} = \frac{\text{MSE using Median} - \text{MSE using MF-ABV}}{\text{MSE using Median}} \%$$

Table 1: MSE for Standard Median and MF-ABV at 3% Noise Level, and the achieved Enhancement

Image	Noise 3%		
	MSE Median	**MSE MF-ABV**	**MSE Enhancement**
Lena	39.71	27.58	44%
Babon	41.79	33.25	26%
Mousq	57.40	61.91	-7%
Barbara	63.35	62.78	1%
Boat	44.65	39.92	12%
House	58.87	52.32	13%
Cameraman	92.89	94.68	-2%
		Average	**12%**

The achieved average of overall MSE enhancement by MF-ABV is 12%. The highest enhancement was with Lena image, it was 44% on the MSE which leads to enhance the quality. Figure 4 is a graphical representation for table 1. It is noticed that in most cases (i.e. with most tested images) that the MSE for MF-ABV is less than the MSE for the standard median filter. The X-coordinate is the achieved MSE, and Y-coordinate is the image number (1: Lena, 2: Babon, 3: Mousqe, 4: Barbara, 5: Boat, 6: House, and 7: Cameraman respectively). The legends in figure 4 (and the remaining figures) as follows:  for MSE produced by MF-ABV and  for MSE by standard median.

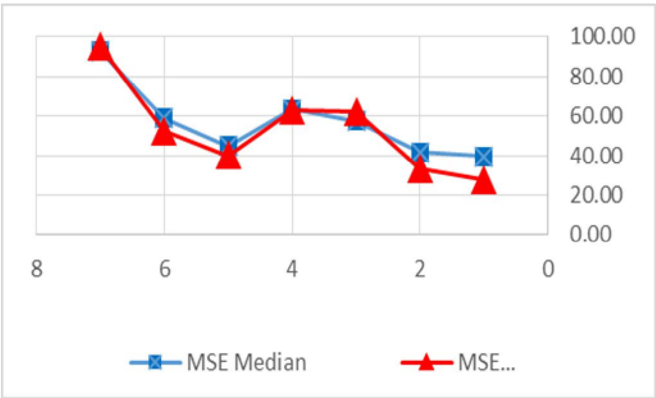

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Figure 4: MSE for Standard Median and MF-ABV at 3% Noise Level

Table 2 show the MSE results for standard median and MF-ABV with the added noise level was 4% on all images. The average enhancement on MSE for all experimented images was 17%. The highest enhancement on the MSE was 40% with Babon image.

Table 2: MSE for Standard Median and MF-ABV at 4% Noise Level, and the achieved Enhancement

Image	Noise 4%		
	MSE Median	MSE MF-ABV	MSE Enhancement
Lena	58.00	44.75	30%
Babon	63.21	45.07	40%
Mousq	76.96	84.85	-9%
Barbara	93.78	89.13	5%
Boat	66.28	53.95	23%
House	85.21	73.41	16%
Cameraman	128.98	112.75	14%
		Average	**17%**

Figure 5 is graphical representation for table 2. It is noticed that the MSE values were least with MF-ABV in most cases in compare with the standard median filter.

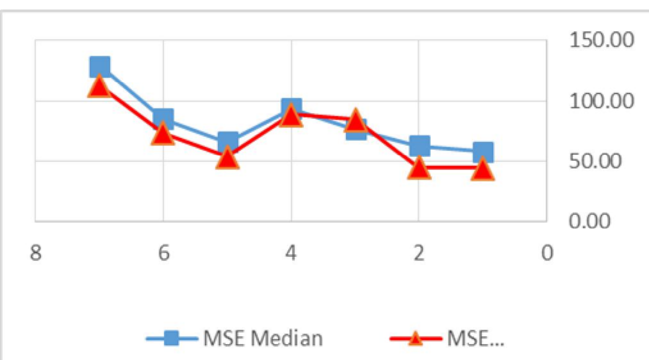

Figure 5: MSE for Standard Median and MF-ABV at 4% Noise Level

In order to test MF-ABV under different circumstances, the noise level is increased on all images to be 5%. Table 3 shows that the average of enhancement on MSE was 12%. The highest enhancement was with Lena image, it was 28%.

Table 3: MSE for Standard Median and MF-ABV at 5% Noise Level, and the achieved Enhancement

Image	Noise 5%		
	MSE Median	MSE MF-ABV	MSE Enhancement
Lena	83.17	65.23	28%
Babon	93.01	76.12	22%
Mousq	113.84	109.08	4%
Barbara	121.65	116.27	5%
Boat	89.85	79.14	14%
House	113.33	101.83	11%
Cameraman	154.52	158.06	-2%
		Average	**12%**

Figure 6 is a graphical representation for table 3. The achieved enhancements on the MSE were decreased in compare with the results when the noise level was 4%. However, it is still better than the MSE with the standard median filter.

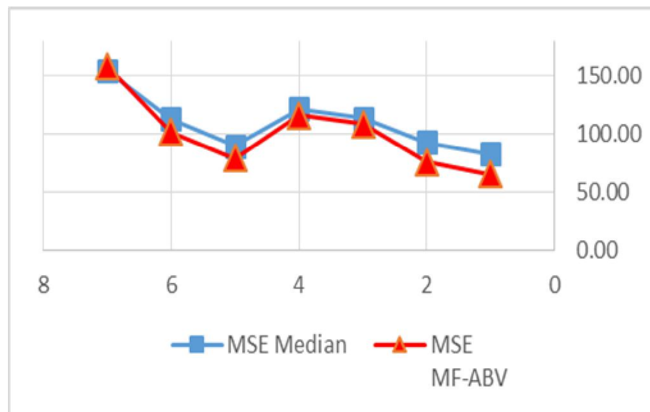

Figure 6: MSE for Standard Median and MF-ABV at 5% Noise Level

Generally, the results of MF-ABV enhances the quality of most filtered images in term of the MSE. Future works could be concentrated to expand the images set and use more noise levels in the experiments.

CONCLUSIONS

This paper proposed a new filtering algorithm to reduce the Salt and Pepper noise from digital images which is an enhanced version of the standard median filter. The proposed algorithm able to be effective perfectly to achieve the better results in term of mean square error (MSE), especially when used mask size 3x3. However, when the used mask size was 5x5 this algorithm became less effective. The experiment results showed that the proposed algorithm works well when the number of noisy pixels are too much especially when the noise level was 4%.

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