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WAF AND WMF TO IMPROVE THE PERFORMANCE OF AVERAGE AND MEDIAN FILTERS

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ABSTRACT

Salt and spice noise is considered one of the most common types of noise that affect grayscale and color digital images, as it affects them negatively, and this negative effect increases with an increase in the noise ratio. Many digital filters are used to mitigate the negative effects of salt and pepper noise, and the most widely used of these filters are the average filter and the median filter. The average and median filters work on processing all pixels in the image, whether these pixels are intact from the noise or infected with it, and accordingly, mitigating this noise, especially if it has a high noise ratio, is ineffective. In this research paper, new window average and window median filters will be proposed to enhance the performance of standard average and median filters. The proposed filter will treat the infected pixels, leaving the clean pixels as they were. For a noisy pixel, a special window will be created and the pixel value will equal the mean (or average) of the cleaned pixels in the window (excluding the noisy pixels). To simplify the window processing an index window will be used, this window will point to the noisy and cleaned pixels in the selected pixel window. Several images with various values of noise ratios will be tested; several windows with different sizes will be examined to get the most suitable window size. The selected window size will be used to filter various noisy images, the obtained results will be compared with average and median filter results to show the improvements provided by the proposed method.

Keywords: SAPN, NR, AF, MF, window, index window, WAF, WMF, PSNR.

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1. INTRODUCTION

Salt-and-pepper noise (SAPN) [1-10] is a type of distortion found in digital images, gray or color, which appears as random black and white spots of light in the image, and its effect is shown in the images taken quickly. The median and the average filters are among the most important methods used to reduce the effect of this phenomenon. The negative effects of SAPN increase when increasing the noise ratio (NR) (number of affected, noisy pixels to total image size) [11-15].

SAPN can affect gray images and color images, the number of zeros and the number of 255s in the noisy image will increase, and the increasing factor depends on the noise ratio (NR) (number of noisy pixels divided by the image size in pixels) as shown in figure 1 [26-30].

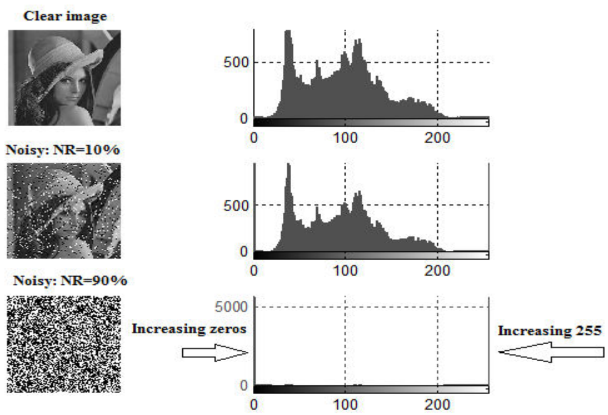

Figure-1. Increasing NR increases 0s and 255s.

Digital gray image [20-25] is a 2D matrix (see Figure-2), each pixel has an integer value within the range 0 to 255.

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Part of the image matrix

52	80	95	103	116	131	141	145	139	138	145
42	67	75	91	100	117	142	148	145	146	148
65	114	103	129	145	145	141	132	143	154	149
81	119	107	141	150	141	141	139	165	155	146
96	117	118	155	147	138	157	151	157	152	142
92	82	140	158	139	142	152	154	162	141	133
116	77	123	136	127	143	156	150	149	139	131
120	78	116	126	122	144	159	148	139	134	132
123	90	126	135	126	143	161	152	138	130	134
144	100	131	137	129	146	168	158	137	130	134
146	102	120	126	130	153	171	156	130	130	131

Figure-2. 2D gray image matrix.

Digital color image [27-30] is one of the most important types of digital data in circulation due to its use in vital and multiple applications that require ridding it of the negative effects of noise effects, including salt and pepper noise [16-20]. Digital color image is a 3 2D matrices (one 2D matrix for each color: red, green, and blue) as shown in figure 3 [30-35]. Each matrix can be extracted and treated separately, and the processed colors matrices can be combined to form a processed digital color image [11-15].

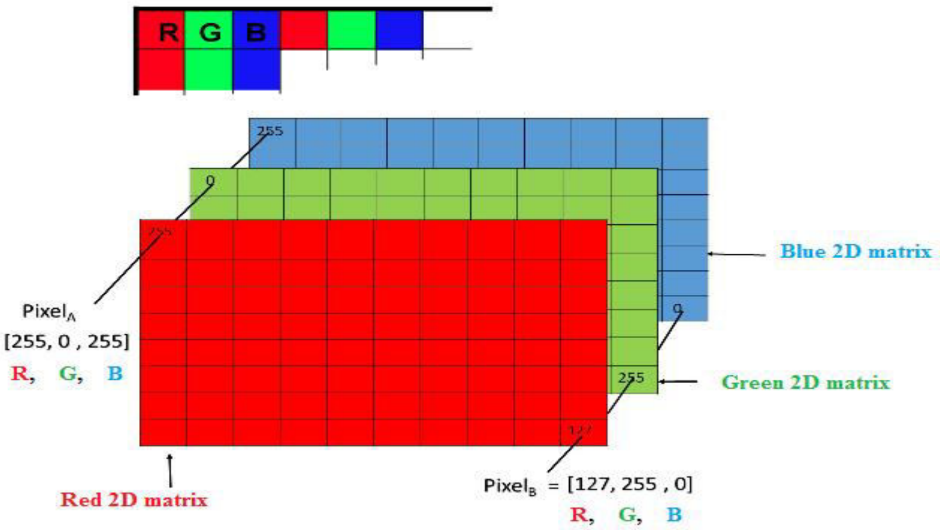

Figure-3. 3D color image matrix.

Digital average filter (AF) acts on all the noisy image pixels by replacing its value with the average of the pixels covered by a window as shown in the figure in Figure-4:

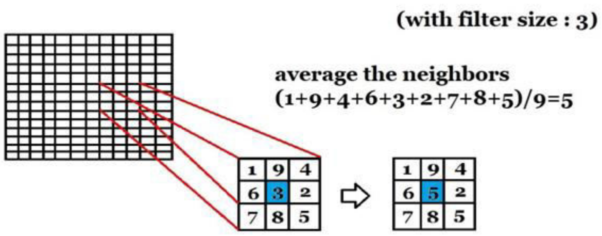

Figure-4. AF operations.

Algorithm 1 shows how to implement AF:

Algorithm 1: AF operations

Step 1: Get the 2D noisy matrix.
Step 2: retrieve the matrix size.
Step 3: For each pixel in the gray image do
Step 4: Get the set of neighbor's values and the pixel value.
Step 5: Find the set of values average.
Step 6: Replace the pixel value with the average value of the set.
Step 7: End for

Digital median filter (MF) acts on all the noisy image pixels by replacing its value with the mead of the pixels covered by a window as shown in the figure in Figure-5:

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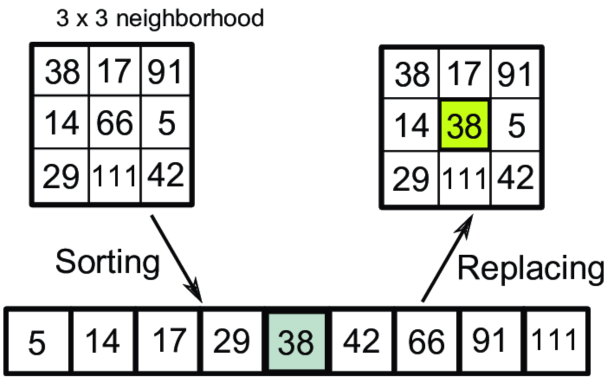

Figure-5. MF operations.

Algorithm 2 shows how to implement MF:

Algorithm 2: MF operations

Step 1: Get the 2D noisy matrix.
Step 2: retrieve the matrix size.
Step 3: For each pixel in the gray image do
Step 4: Get the set of neighbor's values and the pixel value.
Step 5: Sort the set values.
Step 6: Find the mean of the set.
Step 7: Replace the pixel value with the mean value of the set.
Step 8: End for

Color images can be denoised using AF or MF in the same manner by denoising each color alone, then combining the denoised colors into one 3D matrix to get the denoised color image.

AFs and MFs are good to be used to reduce SAPNs with low NRs, when the noise ratio increases these filters will be inefficient as shown in Figures 6, 7, and 8:

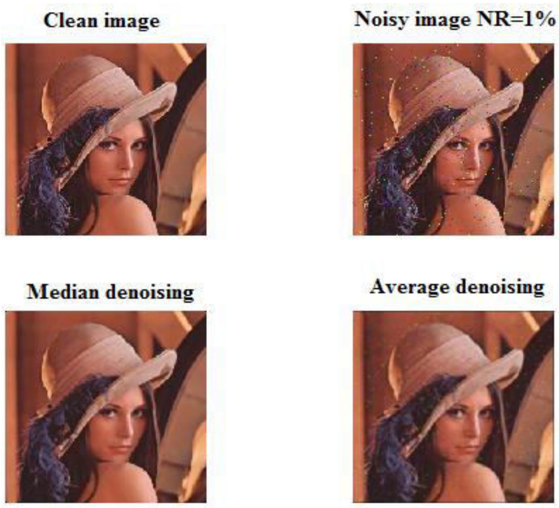

Figure-6. Denoising SAPN with 1% NR.

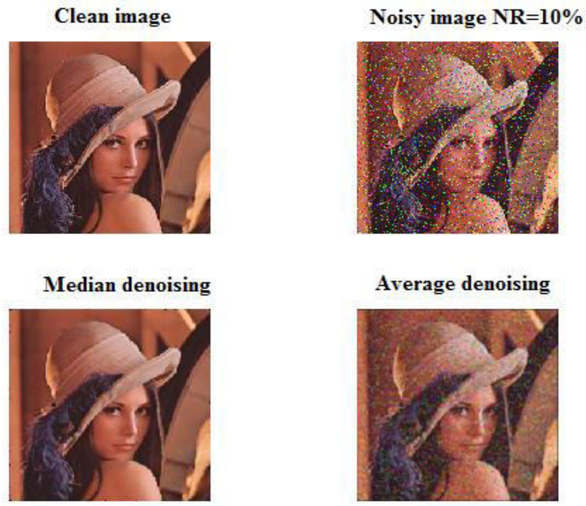

Figure-7. Denoising SAPN with 10% NR.

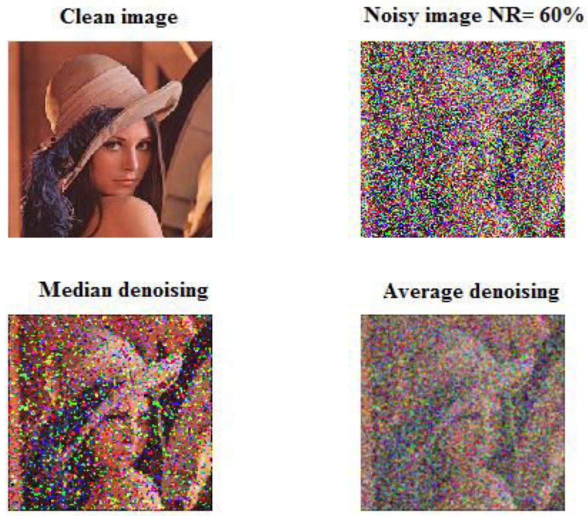

Figure-8. Denoising SAPN with 60% NR.

2. THE PROPOSED WAF AND WMF

The proposed window median filter (WMF) and window average filter (WAF) were introduced to overcome the disadvantages of AF and MF based on the following:

- Treating only the noisy pixels without changing cleaned pixels.
- Using a window to find the mean or the average and replacing the noisy pixel with this mean or average.
- Reducing the effects of high NR.

The proposed method uses two index matrices, one for the noisy image and the other for the padded noisy image. The values of the index matrices are 0s and ones, zeros point to the noisy pixels, and 1s point to the clean pixels [35-40]. A window to find the mean or the average must be selected for the padded noisy matrix; the size of this window will be investigated to find the optimal size,

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which gives the maximum value of peak signal to noise ratio (PSNR) [39-43] calculated between the clean and the denoised images (increasing PSNR mean more image cleaning). Figures 9 to 12 show the matrices used in the proposed method:

Clean image

51	138	75	123
72	31	11	90
60	122	4	1
78	37	178	203

Noisy image

51	138	75	123
72	31	11	90
60	255	4	1
78	37	178	203

Noisy index image

1	1	1	1
1	1	1	1
1	0	1	1
1	1	1	1

Figure-9. Clean and noisy images.

Paded noisy image

203	203	178	37	78	78	37	178	203	203	178	37	78	78
203	203	178	37	78	78	37	178	203	203	178	37	78	78
1	1	4	255	60	60	255	4	1	1	4	255	60	60
90	90	11	31	72	72	31	11	90	90	11	31	72	72
123	123	75	138	51	51	138	75	123	123	75	138	51	51
123	123	75	138	51	51	138	75	123	123	75	138	51	51
90	90	11	31	72	72	31	11	90	90	11	31	72	72
1	1	4	255	60	60	255	4	1	1	4	255	60	60
203	203	178	37	78	78	37	178	203	203	178	37	78	78
203	203	178	37	78	78	37	178	203	203	178	37	78	78
1	1	4	255	60	60	255	4	1	1	4	255	60	60
90	90	11	31	72	72	31	11	90	90	11	31	72	72
123	123	75	138	51	51	138	75	123	123	75	138	51	51
123	123	75	138	51	51	138	75	123	123	75	138	51	51

Figure-10. Padded noisy image.

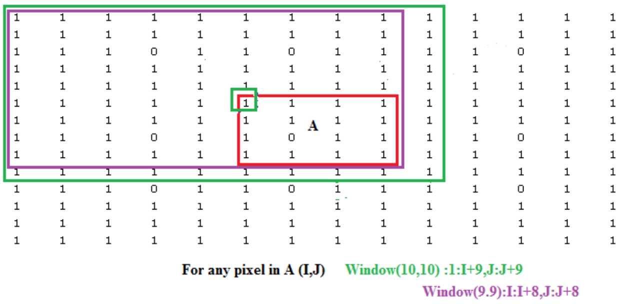

Figure-11. Index padded matrix and windows for pixel (1,1).

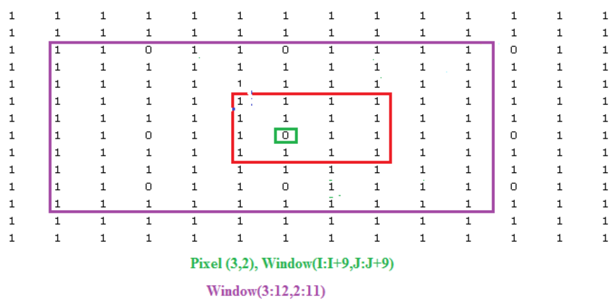

Figure-12. Window 10 by 10 for pixel (3, 2).

Figure-13 shows the obtained denoised images after implementing each method, as shown the output denoised matrix obtained by WMF is very close to the clean matrix.

51	138	75	123
72	31	11	90
60	70	4	1
78	37	178	203

Proposed: Window (I:I+9, J:J+9

WMF

0	31	31	0
51	60	75	4
37	60	37	4
0	37	4	0

MF

32	42	52	33
67	77	81	34
59	81	90	54
48	68	75	43

AF

Figure-13. Obtained denoised matrices.

Algorithm 3 shows the operations of WMF:

Algorithm 3: WMF operations

Step 1: Get the noisy 2D image matrix (A).
Step 2: Retrieve the image size.
Step 3: Pad the noisy image (pA) 5 by 5 to make it possible to use a 10 by 10 window.
Step 4: Select the window size.
Step 5: Pad B 5 by 5.
Step 6: Get the index matrix for the image (B)
Step 7: Get the index matrix for pA.
Step 8: For I 1 to row size of B do
Step 9: For j from 1 to column size B do
Step 10: If B (I, J) equal 1 continue
Step 11: Create a window with the selected sizes.
Step 12: If the window summation equals zero continue
Step 13: From the window get the set of clear pixels.
Step 14: Sort the value and get the mean value.
Step 15: let the pixel equal the mean.
Step 16: End for
Step 17: end for

Below is the mat lab sequence of operation required to implement the WMF algorithm:

```
a=imread('C:\Users\win 7\Desktop\Lena.jpg');
ab=imnoise(a, 'salt & pepper',0.6);
%1: red color denoising
A=ab(:,:,1);
B=(~(A==0 | A==255));
pA=padarray(A,[5 5],'symmetric');
pB=(~(pA==0 | pA==255));
[m,n]=size(B);m*n
% First round
        for I=1:m
          for J=1:n
            if(B(I,J)==0)
                if(sum(sum(pB(I:I+9,J:J+9)))~=0)
                  R1=pA(I:I+9,J:J+9);% W1P creation
                  R1=R1(R1>0 & R1<255);mR=median(R1); A(I,J)=mR;

                end
            end
          end
        end

  X(:,:,1)=A;
```

Algorithm 4 shows the operations of WAF:

Algorithm 4: WAF operations

Step 1: Get the noisy 2D image matrix (A).
Step 2: Retrieve the image size.
Step 3: Pad the noisy image (pA) 5 by 5 to make it possible to use a 10 by 10 window.
Step 4: Select the widow size.
Step 5: Pad B 5 by 5.

Step 6: Get the index matrix for the image (B)
Step 7: Get the index matrix for pA.
Step 8: For I 1 to row size of B do
Step 9: For j from 1 to column size B do
Step 10: If B (I, J) equal 1 continue
Step 11: Create a window with the selected sizes.
Step 12: If the window summation equals zero continue
Step 13: From the window get the set of clear pixels.
Step 14: Find the average value of the set.
Step 15: let the pixel equal the average value.
Step 16: End for
Step 17: end for

Below is the mat lab sequence of operation required to implement the WMF algorithm:

```
a=imread('C:\Users\win 7\Desktop\Lena.jpg');
ab=imnoise(a, 'salt & pepper',0.6);
%1: red color denoising
A=ab(:,:,1);
B=(~(A==0 | A==255));
pA=padarray(A,[5 5],'symmetric');
pB=(~(pA==0 | pA==255));
[m,n]=size(B);m*n
% First round
        for I=1:m
          for J=1:n
             if(B(I,J)==0)
                 if(sum(sum(pB(I:I+9,J:J+9)))~=0)
                  R1=pA(I:I+9,J:J+9);% W1P creation
                  R1=R1(R1>0 & R1<255);mR=mean(R1); A(I,J)=mR;

                 end
             end
          end
        end

  X(:,:,1)=A;
```

3. IMPLEMENTATION AND RESULT DISCUSSION

The color image lena.jpg was affected by SAPN with various NR values; Figures 14, 15, and 16 show the results of applying the proposed WMF and WAF (Window size is 10 by 10)

Noisy image | Denoising using WMF | Denoising using WAF

Figure-14. Denoising 10 % NR.

NR=10%

Noisy image | Denoising using WMF | Denoising using WAF

Figure-15. Denoising 30 % NR.

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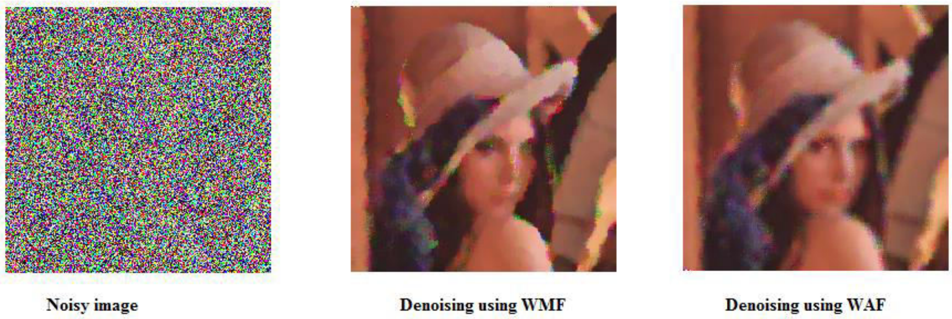

Figure-16. Denoising 90 % NR.

As we can see from the previous figures the proposed methods WMF and WAF can be used efficiently to reduce the effects of SAPN with any NR.

A noisy image (lena.png) with various values of NR was treated using various window sizes; Tables 1 through 4 show the obtained PSNR values for each case:

Table-1. Obtained results NR=0.1%.

Window size	WMF PSNR	WAF PSNR
10 by 10	106.2950	102.3198
10 by 9	103.7376	101.6334
9 by 10	104.6423	102.2263
9 by 9	103.9575	102.2702
8 by 8	103.9575	102.3684
7 by 7	98.0338	100.8153
6 by 6	98.2008	99.5818
5 by 5	96.3258	98.4235

Table-2. Obtained results NR=1%.

Window size	WMF PSNR	WAF PSNR
10 by 10	99.2174	94.6460
10 by 9	95.6628	94.8089
9 by 10	97.6819	94.2734
9 by 9	96.2487	94.1885
8 by 8	93.3571	94.3745
7 by 7	90.2925	92.7935
6 by 6	88.9849	89.7776
5 by 5	86.6128	88.8998

Table-3. Obtained results NR=10%.

Window size	WMF PSNR	WAF PSNR
10 by 10	79.3353	76.8626
10 by 9	78.3046	76.6461
9 by 10	78.6824	77.1067
9 by 9	77.6490	77.0132
8 by 8	74.7037	75.5273
7 by 7	71.8751	73.6564
6 by 6	69.6088	70.9689
5 by 5	68.0268	68.6320

Table-4. Obtained results NR=90%.

Window size	WMF PSNR	WAF PSNR
10 by 10	53.6565	53.6098
10 by 9	53.2087	53.7121
9 by 10	53.2517	53.4053
9 by 9	52.9519	53.2940
8 by 8	50.3104	51.1743
7 by 7	46.3215	46.9451
6 by 6	40.8204	40.9342
5 by 5	34.4771	34.8086

From the previous tables we can see that using a window with size 10 by 10 gives the best values for PSNR, increasing the window size will increase PSNR value for both proposed filters WMF and WAF, WMF provides better results comparing with WAF.

To show the improvements provided by the proposed filters the color image lena.jpg was affected by SAPN with various NR values, the noisy images were processed using WMF, WAF (window size 10 by 10), MF and AF, Table-5 shows the obtained results:

Table-5. PSNR results for various filters using various NR.

NR %	WMF	WAF	MF	AF
0.1	105.6142	102.0420	74.2442	66.5257
1	98.7609	94.6943	73.9702	64.2177
10	79.2401	77.3610	69.5446	52.3074
20	72.3310	70.0364	62.2186	45.8579
30	68.5462	66.3555	52.0048	41.2324
40	65.6787	63.4706	42.6100	37.7080
50	62.8842	61.1538	33.8419	34.5011
60	60.8496	59.2041	27.5567	32.0986
70	59.1449	57.6244	22.2581	29.7829
80	56.8837	56.0689	17.9746	27.8469
90	53.4862	53.6322	14.4438	25.9324

As we can see from table 5 the proposed WMF and WAF provided a significant improvements by enhancing the PSNR value for SAPN with any NR value, this is shown in Figure-17.

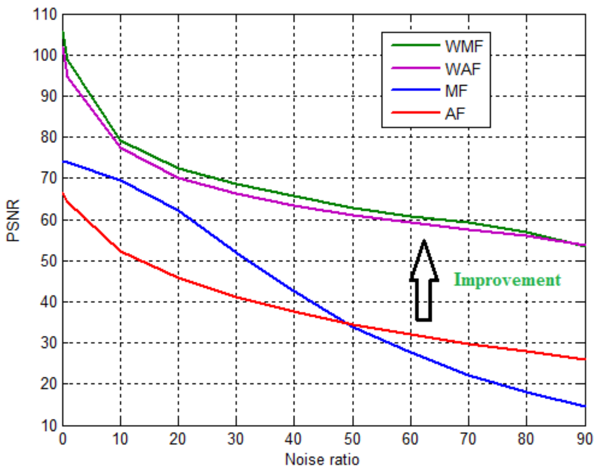

Figure-17. PSNR comparison.

4. CONCLUSIONS

An efficient method of window median and window average filters were introduced, these filters can be efficiently used to reduce the effects of salt and pepper noise with any noise ratio (Low and high NR). The proposed method used a window to treat the noisy pixels, the size of this window was tested and it was recommended to use a window of 10 by 10, this window gave the optimal PSNR values for any noise ratio. It was shown that average and median filters failed to treat the noise with high ratios, using the proposed method solved this problem.

The proposed method used an index matrix to simplify the process of detecting noisy pixels; this matrix was easily used to create the required filter window.

The proposed filters were tested using various affected images with various noise ratio values, the obtained results showed that the proposed method provided a good improvement for all noise ratios (Low and high noise ratio), the proposed method significantly increased the values of PSNR, thus the proposed method efficiently decreased the effects of salt and pepper noise.

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