Available Online at www.ijcsmc.com/journal

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 7.056

IJCSMC, Vol. 11, Issue. 6, June 2022, pg.169 – 189

Multiple_Window Median Filter (MWMF) for Efficient Removing Salt and Pepper Noise

Prof. Qazem M. Jaber; Prof. Ziad A. Alqadi; Holwa F. Taha
Albalqa Applied University
Jordan, Amman
DOI: https://doi.org/10.47760/ijcsmc.2022.v11i06.013

Abstract:

Salt and pepper noise is one of the most common types of noise that affects color and gray digital images, as this noise negatively affects the characteristics of the image and becomes blurred. And since the digital image is used in vital and important applications, it is necessary to provide an effective method that reduces the negative effects of noise. An easy and effective method will be presented that reduces the negative effects of salt and pepper noise, regardless of the noise ratio value in the digital image. In the proposed method, a set of windows will be used that is generated from the output of the affected image padding process, and these windows will be used to check the pixel is noise or not to be processed if this pixel is noise, using the specified window and applying the process of the median filter to this window. The proposed method will be implemented using various color and gray images, the quality parameters MSE and PSNR will be calculated. The obtained results for the proposed method will be compared with the results of median, MDBUT MF, MDBPT GMF, AWMF; AAMF filters to show the enhancement of the proposed method in reducing the negative effects of salt and pepper noise.

Keywords: SAPN, NR, median filter, PM, RM, PW, RW, MSE, PSNR, CC.

Introduction

Digital images, whether gray or color [12], [13], are considered one of the most widespread types of digital data, as they have been used in many vital and important applications [24-29].
Digital images are easy to process because the gray image is represented by a two-dimensional matrix, while the color image is represented by a three-dimensional matrix (a two-dimensional matrix for each of the three colors: red, green and blue) [14-18].
Digital images are circulated through various social media, and while these images are transmitted, they can be affected by the noise of salt and pepper (SAPNR), which negatively affects their properties and the image becomes

unclear to the naked eye. The negative effect increases by increasing the number of affected pixels, or the so-called noise ratio (NR), which represents the ratio of the affected pixels to the total number of pixels in the image [1-9].

SAPN replaces some pixels in the image by zeros or 255s, thus the repetition of these values will be increased by increasing NR, and figure 1 shows the how SAPN affects a gray image, while figures 2 and 3 show how SAPN affects color image[30-37].

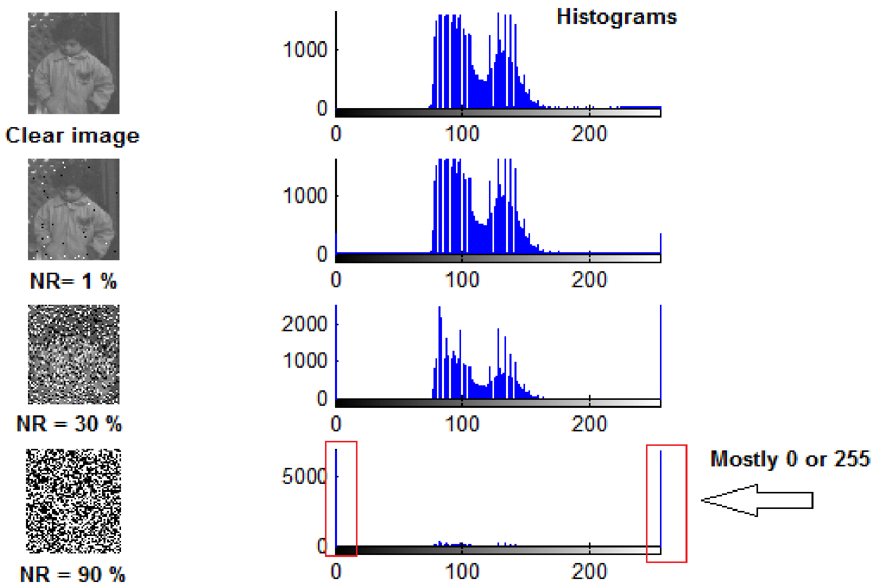

Figure 1: Affected by SAPN gray images

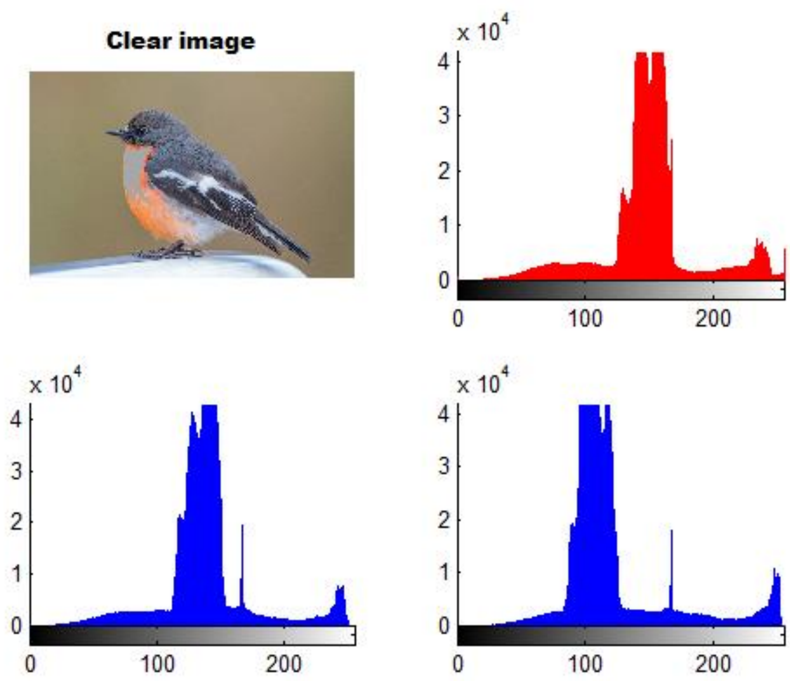

Figure 2: Clear color image example

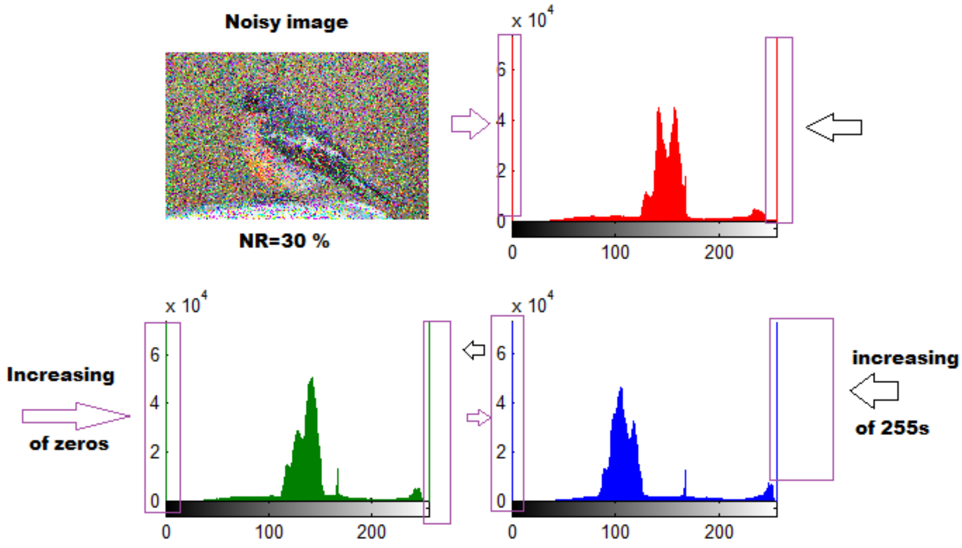

Figure 3: Noisy color image

The efficiency of any digital filter used to reduce the effects of SAPN can be measured by the quality parameters: mean square error (MSE), peak signal to noise ratio (PSNR) and correlation coefficient between a source clear image and the treated by the filter image (de-noised image), these parameters can be calculated using equations 1, 2 and 3 [19-24].

MSE of x channel

$$MSE_x = \frac{1}{N}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[S(i,j) - R(i,j)]^2 \;, N = m * n \quad (1)$$

Total MSE

$$MSE_t = MSE_R + MSE_G + MSE_B$$

Calculate PSNR

$$PSNR = 10 * \log_{10}\frac{(MAX_I)^2}{MSE_t} \quad (2)$$

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (3)$$

Where

r = **correlation coefficient**

x_i = **values of first image matrix**

$\bar{x}$ = **mean of x matrix**

y_i = **values of second image matrix**

$\bar{y}$ = **mean of y matrix**

Most of the digital filters used to de-noise images operate with a selected window; in our research paper we will use the feature of padding the image matrix to create the necessary windows. In our method we will use two kinds of padded matrices to generate two kinds of windows. The first padded matrix will be called processing matrix (PM), which will be used in mean finding applying the processing window (PW). The second padding matrix will be used as a reference matrix (RM), the values of RM will be zeros or 1s, 0 means that the associated pixel in PM is a noise, 1 means that the pixel is not a noisy pixel, RM will be used to generate reference windows (RW), figures 4, 5 and 6 illustrates an examples of these matrices [38-44]

138	128	0	14	242
208	13	213	255	206
107	191	46	107	227
41	3	0	216	189
179	93	13	5	173

Noisy matrix (A)

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

Reference matrix (B)

Figure 4: Noisy matrix and its reference

46	191	107	107	191	46	107	227	227	107	46
213	13	208	208	13	213	255	206	206	255	213
0	128	138	138	128	0	14	242	242	14	0
0	128	138	138	128	0	14	242	242	14	0
213	13	208	208	13	213	255	206	206	255	213
46	191	107	107	191	46	107	227	227	107	46
0	3	41	41	3	0	216	189	189	216	0
13	93	179	179	93	13	5	173	173	5	13
13	93	179	179	93	13	5	173	173	5	13
0	3	41	41	3	0	216	189	189	216	0
46	191	107	107	191	46	107	227	227	107	46

Padded A (PM)
Padding factor 3 by 3

Figure 5: Processing matrix (PM)

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

Padded B (RM)

Figure 6: Reference matrix (RM)

Processing and reference matrices are used to create the necessary processing (PW) and reference (RW) windows as shown in figures 7 and 8:

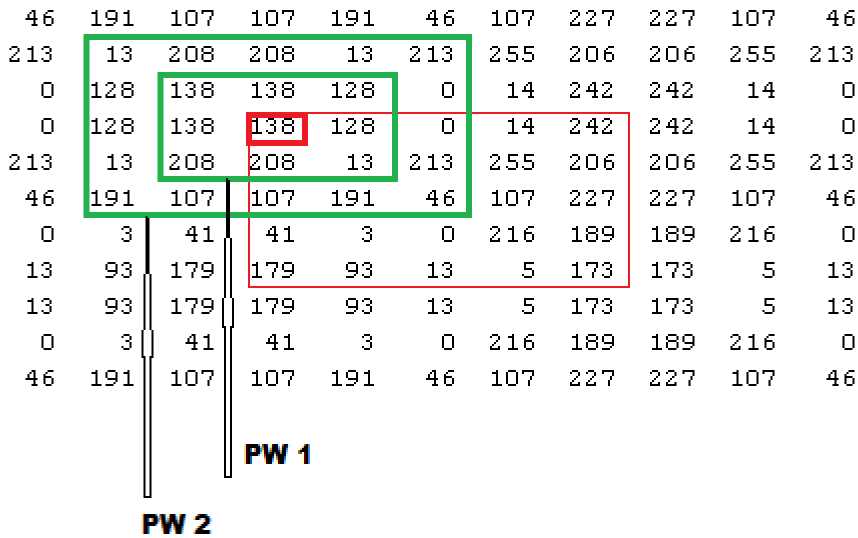

Figure 7: Creating processing windows (PW)

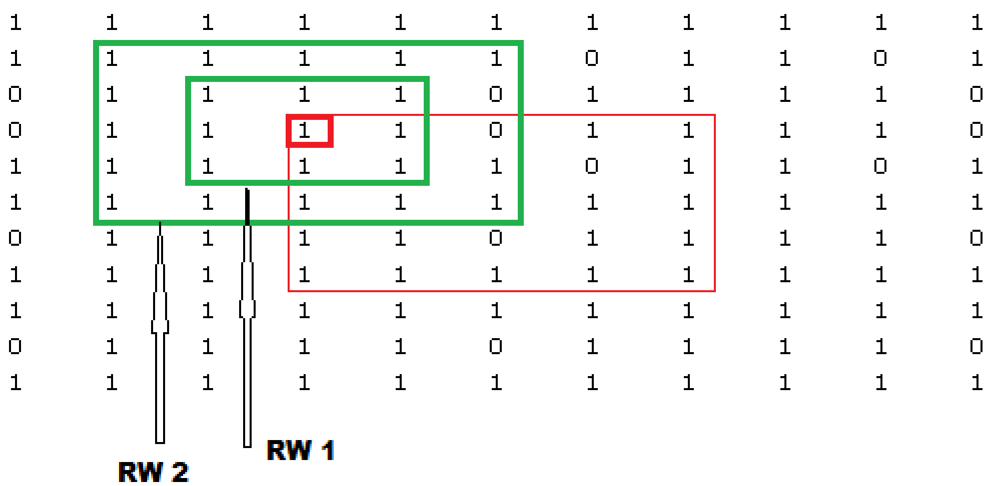

Figure 8: Creating reference windows (RW)

Related Works

A good method of SAPN reduction from gray image or color image is considered to be good if it provides good values for the quality parameters MSE, PSNR and CC, thus it must:

- Minimize the value of MSE.
- Maximize the value of PSNR.
- Make the value of CC very closed to 1.

Many methods are now used to reduce the negative effects of SAPN, most of these methods are based on median filter (MF), this filter (as shown in figure 9) uses a mask of a selected size (usually 3 by 3), this mask will use the corresponding pixels covered by the mask, these pixels' values will have arranged in an array, the array then to be sorted and the denoised pixel will equal the median value of the sorted array.

Median filter has some disadvantages which must be solved such as:

- All the pixels including the clear pixels will be treated by median filters, this will negatively affect MSE, PSNR, and CC.
- Increasing NR of SAPN noise will negatively affect the performance of MF, making MSE high and PSNR low.

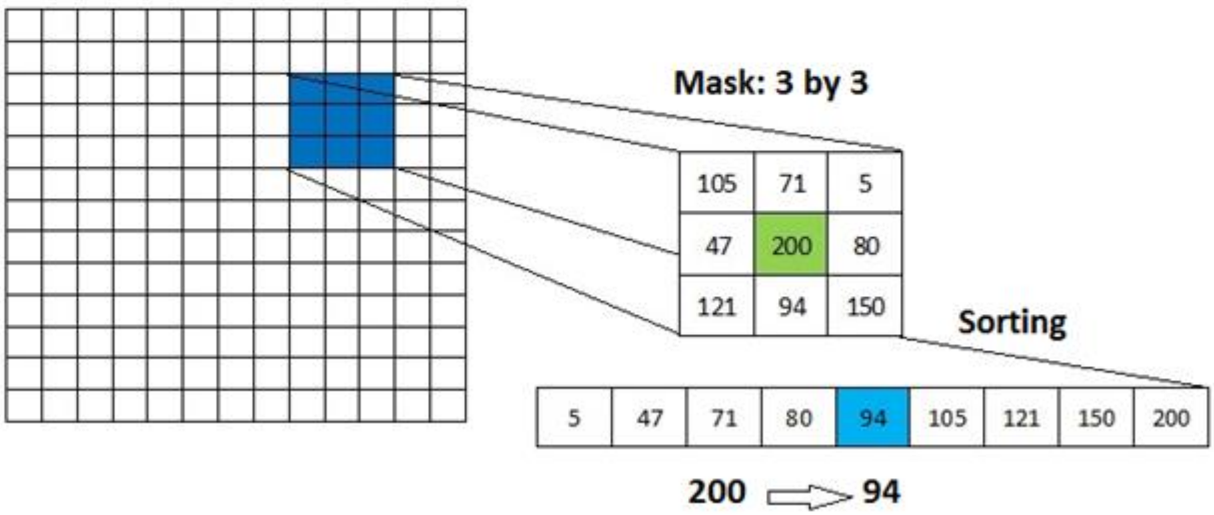

Figure 9: Median filter operations

Many methods were introduced and to be used to reduce the negative effects of SAPN, most of the methods were based on median filter based on median [1-9]. These methods are: Modified Decision Based Unsymmetrical Median Filter (MDBUTMF) [7], Decision Based Partially Trimmed Global Mean Filter (DBPTGMF) [8], Modified Decision Based Partially Trimmed Global Mean Filter (MDBPTGMF) [9], Adaptive Weighted Mean Filter (AWMF) [11] and Adaptive Approach (AAMF), [10]. These methods add an improvement to salt and pepper noise reduction and increase the filtering efficiency by increasing PSNR between the clear and denoised images.

Proposed Method

The proposed method has the following features:

- It is based on MF.
- It treats only the affected by SAPN pixels, the clear pixels will not be processed, thus it will enhance the method performance by decreasing MSE and increasing PSNR.
- It uses a special data structures to handle the process of noise reduction, these structures are not fixed and the can be expanded to cover windows with big sizes. The strictures maintained by the proposed method contain a processing matrix (PM) and a reference matrix (RM) as explained earlier. These two matrices are used to create the needed windows (PWs and RWs), figures 10, 11, and 12 illustrate an example of how to create these matrices.

201	71	186
154	127	73
34	181	50

Figure 10: Noisy 'image' example

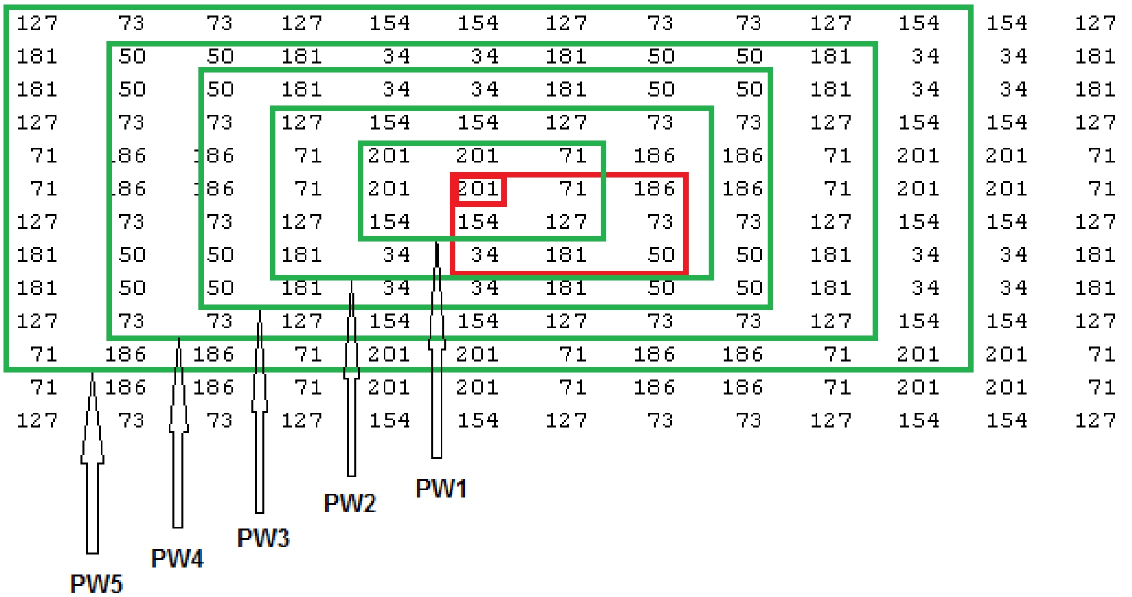

Figure 11: Padded processing to create PM

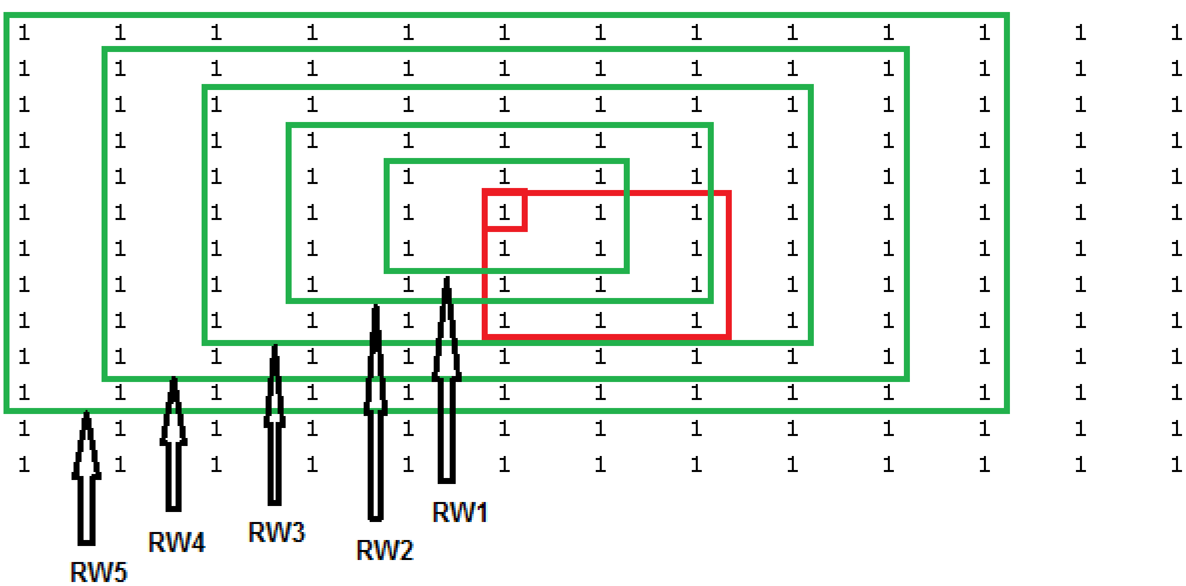

Figure 12: Padded reference matrix (padding 5 by 5)

For each pixel P (i, j) and with padding factor 5 by 5 the needed PWs are shown in table 1, while table 2 shows the reference windows (RFs)in the noisy image extract the processing window from PA matrix.

Table 1: Required processing windows (PWs)

Window	Size	First dimension	Second dimension
PW1	3 by 3	i-1+5:i+1+5	j-1+5:j+1+5
PW2	5 by 5	i-1+4:i+1+6	j-1+4:j+1+6
RW3	7 by 7	i-1+3:i+1+7	j-1+3:j+1+7
PW4	9 by 9	i-1+2:i+1+8	j-1+2:j+1+8
PW5	11 by 11	i-1+1:i+1+9	j-1+1:j+1+9

Table2: Required reference windows (RWs)

Window	Size	First dimension	Second dimension
RW1	3 by 3	i-1+5:i+1+5	j-1+5:j+1+5
RW2	5 by 5	i-1+4:i+1+6	j-1+4:j+1+6
RW3	7 by 7	i-1+3:i+1+7	j-1+3:j+1+7
RW4	9 by 9	i-1+2:i+1+8	j-1+2:j+1+8
RW5	11 by 11	i-1+1:i+1+9	j-1+1:j+1+9

Below is the description of the algorithm of the proposed method:

Inputs

Noisy image

Output

De-noised image

Process:

1. *Get the noisy image B.*
2. *Retrieve the image size.*
3. *Create the padded matrix (PM) pA.*
4. *Create the padded reference matrix (RM) pB.*
5. *Make the denoised image (A) equal the noisy image.*
6. *For each pixel in the noisy image do*
7. *If the pixel not equal 0 or the pixel not equal 255 move the pixel to the denoised image and continue to other pixel, else proceed to the next step.*
8. *Create RWs and PWs and process the steps shown in figure 13:*

```
if(B(i,j)==0)
        if(sum(sum(pB(i-1+5:i+1+5,j-1+5:j+1+5)))~=0)            RW1
          R1=pA(i-1+5:i+1+5,j-1+5:j+1+5);                        PW1
          R1=R1(R1>0 & R1<255);
          mR=median(R1);
          A(i,j)=mR;
        elseif(sum(sum(pB(i-1+4:i+1+6,j-1+6:j+1+6)))~=0)        RW2
          R1=pA(i-1+4:i+1+6,j-1+6:j+1+6);                        PW1
          R1=R1(R1>0 & R1<255);
         mR=median(R1);
          A(i,j)=mR;
        elseif(sum(sum(pB(i-1+3:i+1+7,j-1+3:j+1+7)))~=0)        RW3
         R1=pA(i-1+3:i+1+7,j-1+3:j+1+7);                         PW3
          R1=R1(R1>0 & R1<255);
          mR=median(R1);
          A(i,j)=mR;
          elseif(sum(sum(pB(i-1+2:i+1+8,j-1+2:j+1+8)))~=0)      RW4
         R1=pA(i-1+2:i+1+8,j-1+2:j+1+8);                         PW4
          R1=R1(R1>0 & R1<255);
          mR=median(R1);
          A(i,j)=mR;
          elseif(sum(sum(pB(i-1+1:i+1+9,j-1+1:j+1+9)))~=0)      RW5
         R1=pA(i-1+1:i+1+9,j-1+1:j+1+9);                         PW5
          R1=R1(R1>0 & R1<255);
          mR=median(R1);
          A(i,j)=mR;
        end
```

Figure 13: Checking RWs and processing PWs

Implementation and Experimental Results

The proposed method was implemented using gray images affected with SAPN with various noise ratios, figures 14 and 15 shows an outputs examples:

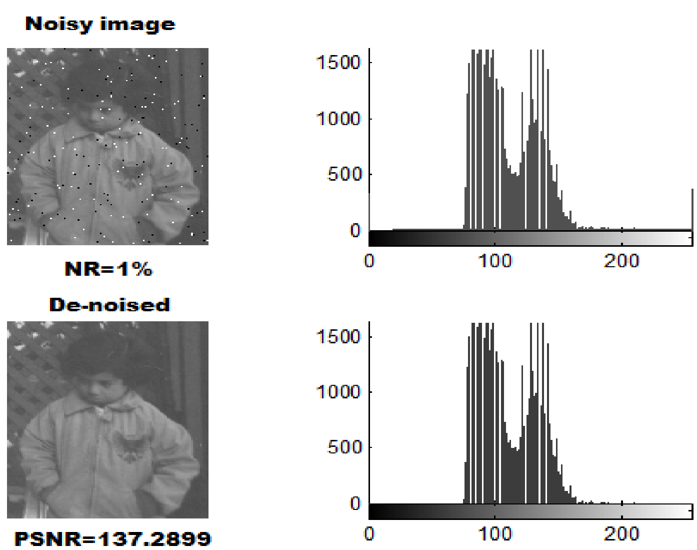

Figure 14: Denoising gray image with low NR

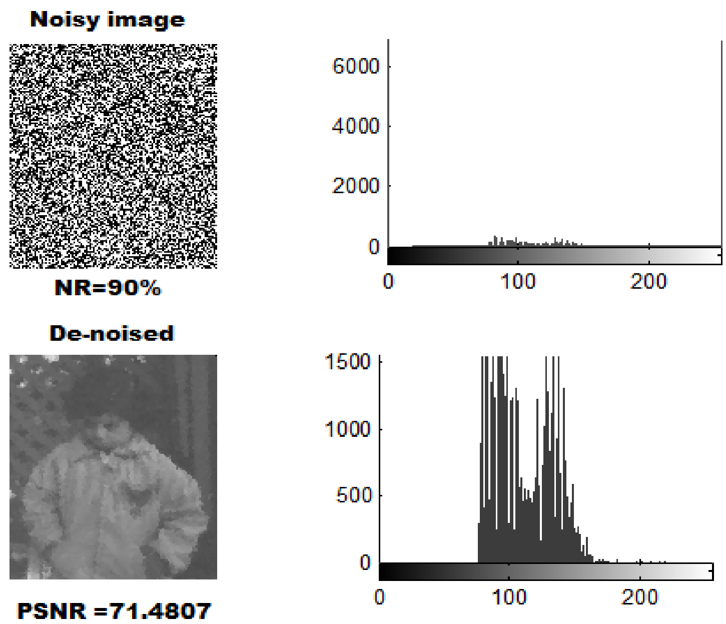

Figure 15: Denoising gray image with high NR

The gray image 'pout.tif' was affected with SAPN using various values of NR, median filter and the proposed method were used to reduce the noise in each noisy image, table 3 shows the obtained results:

Table 3: Denoising 'pout.tif' using MF and the proposed filter

NR %	Median filter			Proposed		
	MSE	PSNR	CC	MSE	PSNR	CC
1	4.6919	92.7745	0.9957	0.0547	137.2899	0.9999
5	6.3801	92.2934	0.9941	0.2611	121.6621	0.9998
10	13.0333	85.1502	0.9879	0.5807	113.6682	0.9995
20	55.5505	70.6523	0.9508	1.7395	102.6970	0.9984
30	240.3579	56.0040	0.8236	2.7291	98.1933	0.9975
40	691.9766	45.4297	0.6431	4.3273	93.5835	0.9960
50	1724.7	36.2970	0.4478	6.4650	89.5689	0.9940
60	3495.6	29.2328	0.2924	9.1017	86.1483	0.9915
70	5760.5	24.2375	0.2077	13.3083	82.3491	0.9876
80	9023.4	19.7495	0.1249	21.2753	77.6575	0.9801
90	1276.7	16.2792	0.0510	39.4573	71.4807	0.9630

From table 3 we can see that the proposed filter is more efficient comparing with MF, the proposed method increased PSNR and decreased MSE for all images with low and high NR, this is shown in figures 16 and 17.

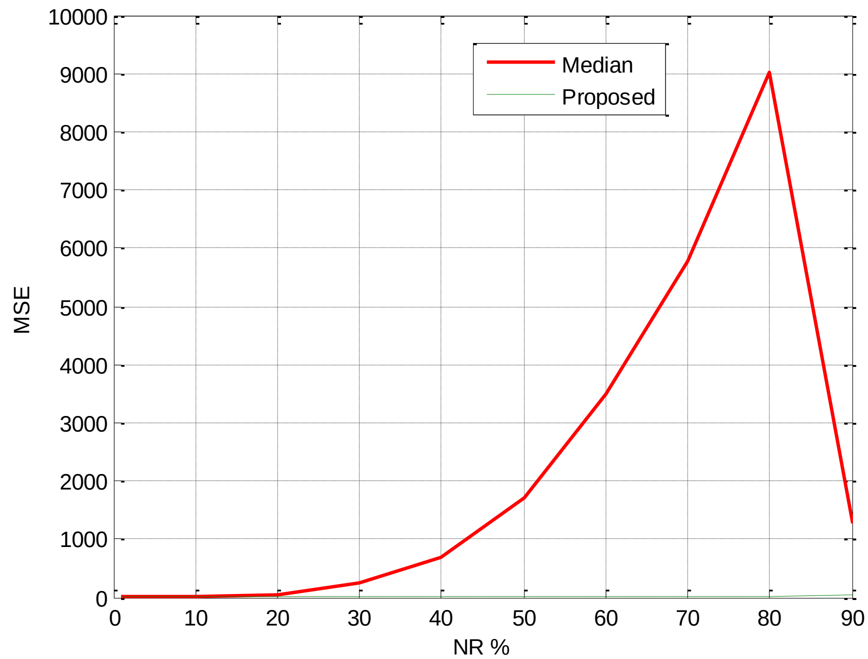

Figure 16: MSE for MF and the proposed filter

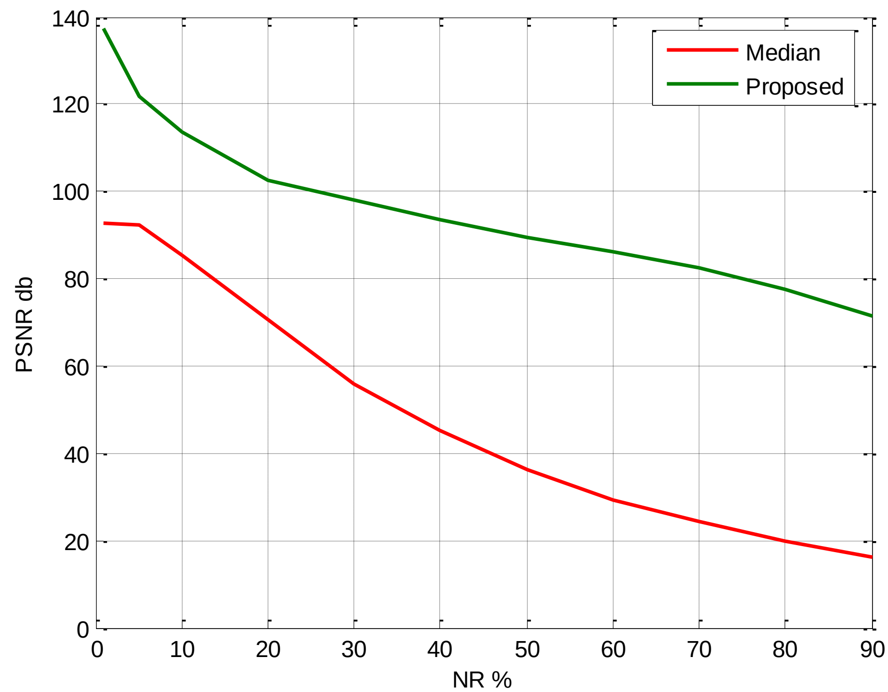

Figure 17: PSNR for MF and the proposed filter

The previous mentioned (in related works) were also implemented and the obtained results for these filters were compared with the results of implementing the proposed filter, table 4 shows the results of comparisons:

Table 4: Filters comparisons

NR %	PSNR				
	Proposed	MDBUT MF	MDBPT GMF	AWM F	AAMF
10	113.6682	106.0674	104.9845	111.4240	112.4038
20	102.6970	101.2922	102.0092	102.2062	109.6104
30	98.1933	81.2179	82.3682	85.8416	91.9312
40	93.5835	63.9605	65.0165	67.3288	70.7881
50	89.5689	50.3720	51.9859	52.4341	54.1376
60	86.1483	38.7028	40.1875	41.6846	44.4209
70	82.3491	30.1583	30.4933	32.0426	38.5340
80	77.6575	25.6423	27.2584	28.4141	30.3927
90	71.4807	24.5940	26.2044	27.5703	26.5740

From table 4 we can see the following:

- The proposed filter can be efficiently used to eliminate SAPN with low and high NRs.
- The proposed method has the best efficiency comparing with other filters and as shown in figure 18.

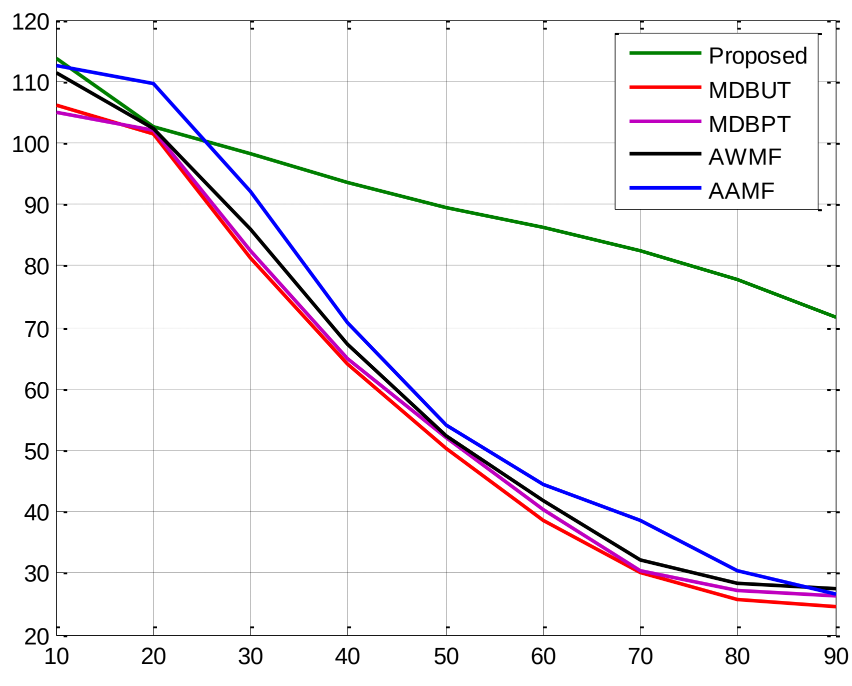

Figure 18: PSNR comparisons

The padding factor was expanded to 6 by 6 using 6 RWs and 6 PWs, here for our case the results were not enhanced as shown in table 5

Table 5: Expanding the padding factor

NR %	Proposed padding 5 by 5 5 windows used			Proposed padding 6 by 6 6 windows used		
	MSE	PSNR	CC	MSE	PSNR	CC
1	0.0547	137.2899	0.9999	0.0435	139.5929	1
5	0.2611	121.6621	0.9998	0.4147	117.0338	0.9996
10	0.5807	113.6682	0.9995	3.5569	95.5439	0.9967
20	1.7395	102.6970	0.9984	7.1574	88.5514	0.9933
30	2.7291	98.1933	0.9975	10.5966	84.6275	0.9901
40	4.3273	93.5835	0.9960	14.6836	81.3656	0.9863
50	6.4650	89.5689	0.9940	19.6633	78.4454	0.9816
60	9.1017	86.1483	0.9915	24.3505	76.3074	0.9772
70	13.3083	82.3491	0.9876	30.3615	74.1012	0.9716
80	21.2753	77.6575	0.9801	35.8083	72.4511	0.9665
90	39.4573	71.4807	0.9630	55.8283	68.0101	0.9478

Using various noisy images with various values of NR can affect the efficiency of the proposed method, and the efficiency will be better than the efficiency of any other filter, tables 6, 7 and 8 show the obtained efficiency parameters as a results of Denoising various images with various values of NR.

Table 6: Denoising SAPN with NR =1%

Image number	Size(byte)	MSE	PSNR	CC
1	50283	12.7294	85.3862	0.9991
2	25992	9.5343	88.2763	0.9975
3	172800	21.3501	80.2147	0.9973
4	1713600	0.7618	113.5465	0.9998
5	1442070	0.7462	113.0346	0.9999
6	40755	3.0321	99.6542	0.9989
7	172800	57.9675	70.2264	0.9932
8	50325	1.2356	108.7100	0.9999
9	50325	2.1464	103.1873	0.9996
10	50451	7.1549	91.1473	0.9992
11	630000	10.1023	87.6976	0.9990
12	2039752	0.1472	129.6715	0.9999

Table 7: Denoising SAPN with NR =30%

Image number	Size(byte)	MSE	PSNR	CC
1	50283	277.6860	54.5604	0.9794
2	25992	203.6778	57.6599	0.9446
3	172800	530.9132	48.0793	0.9331
4	1713600	30.0606	76.7931	0.9931
5	1442070	30.4923	75.9319	0.9952
6	40755	107.8382	63.9404	0.9618
7	172800	1674.3	36.5935	0.8170
8	50325	18.0317	81.9040	0.9983

9	50325	0.9869	68.6750	0.9869
10	50451	225.0636	56.6614	0.9734
11	630000	113.5158	63.5059	0.9891
12	2039752	6.0669	92.4806	0.9974

Table 8: Denoising SAPN with NR =90%

Image number	Size(byte)	MSE	PSNR	CC
1	50283	1867.0	35.5046	0.8601
2	25992	1238.1	39.6121	0.6658
3	172800	2157.6	34.0579	0.7393
4	1713600	272.8938	54.7344	0.9372
5	1442070	290.9865	54.0925	0.9543
6	40755	5576.1	24.5627	0.4682
7	172800	5559.9	24.5919	0.4650
8	50325	155.3153	60.3707	0.9849
9	50325	491.0800	48.8592	0.9040
10	50451	1325.4	38.9308	0.8419
11	630000	0.9419	46.7346	0.9419
12	2039752	55.4317	70.6738	0.9763

The proposed filter can be easily used to reduce SAPN from color image, here each color channel is to be treated alone as a gray image, after Denoising the colors, the colors are to be combined to form the denoised color image.

Figure 19, 20 and 21 show sample outputs of using color image with small size, while table 9 shows the results of denoising this image.

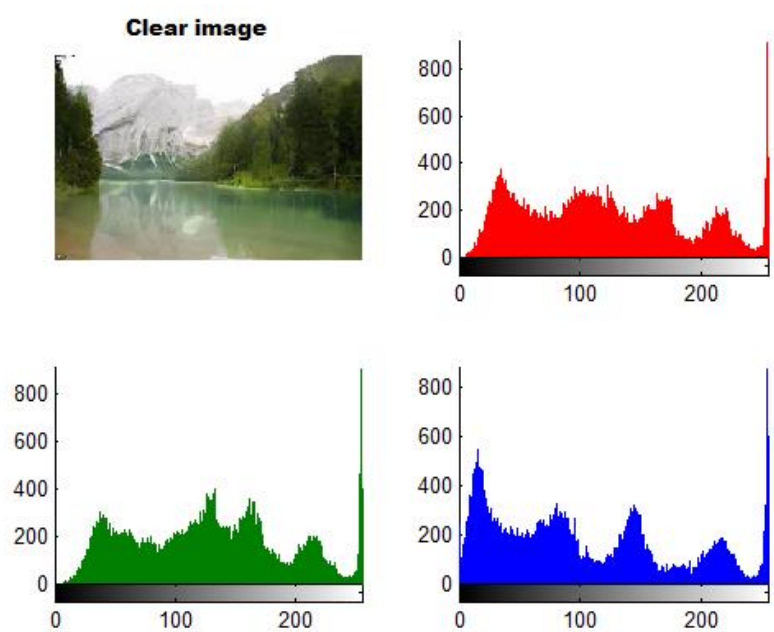

Figure 19: color image with size=150975 bytes

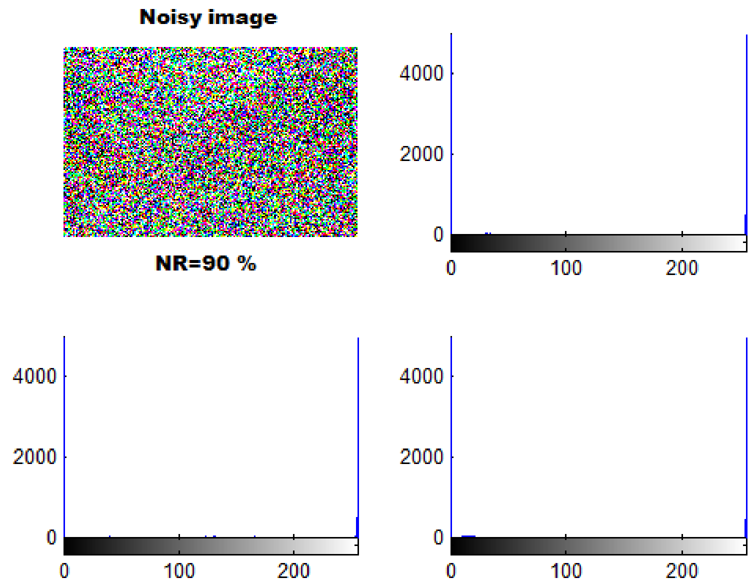

Figure 20: Noisy image with high NR

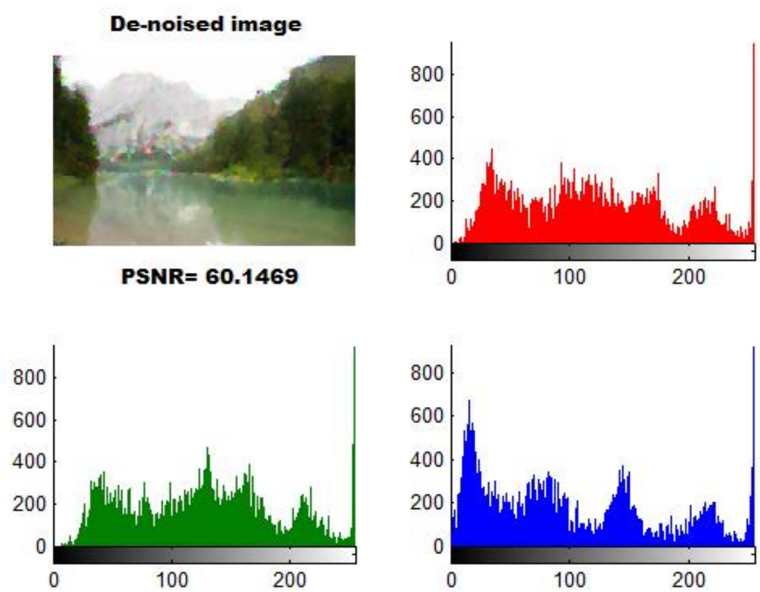

Figure 21: Denoised image

Table 9: Denoising color image with size= 150975 bytes

NR %	MSE	PSNR
0.5	1.5946	106.1593
1	1.7926	104.9884
2	2.2456	102.7357

3	2.7305	100.7803
4	3.2247	99.1168
5	3.5534	98.1463
10	6.3517	92.3380
30	18.9472	81.4087
50	36.5044	74.8509
70	70.4214	68.2803
90	158.8311	60.1469

Another color image with bigger size (size = 6119256 bytes) was also treated using the proposed method, figures 22, 23, and 24 show sample outputs, while table 10 shows the obtained results

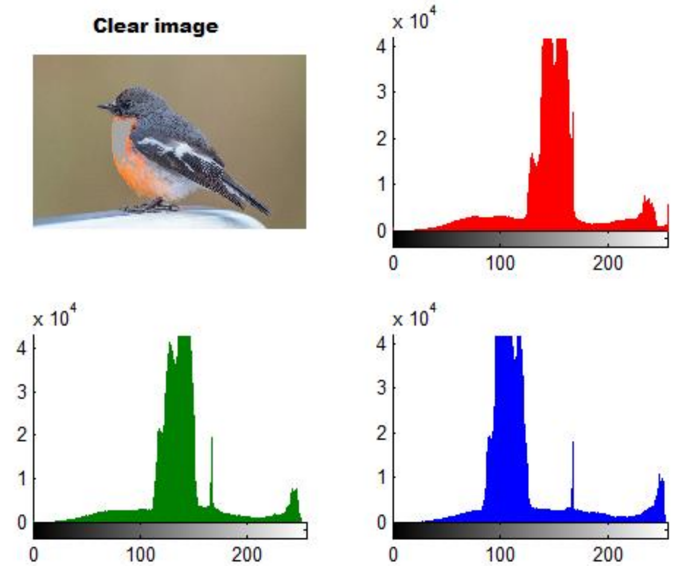

Figure 22: Color image with size = 6119256 bytes

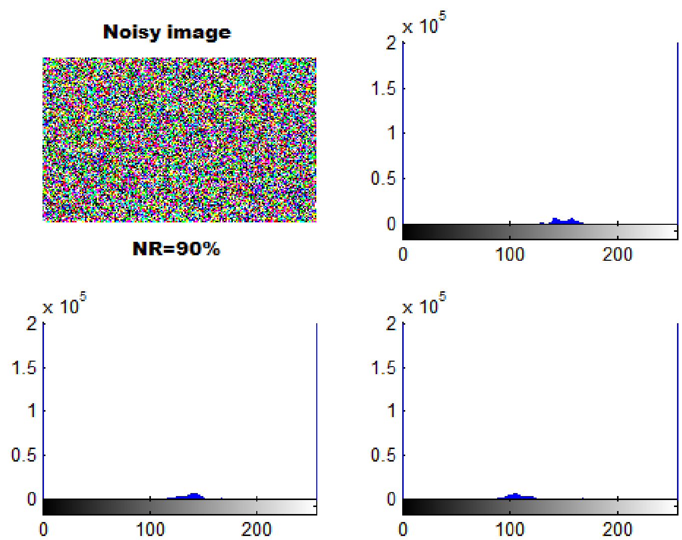

Figure 23: Noisy image

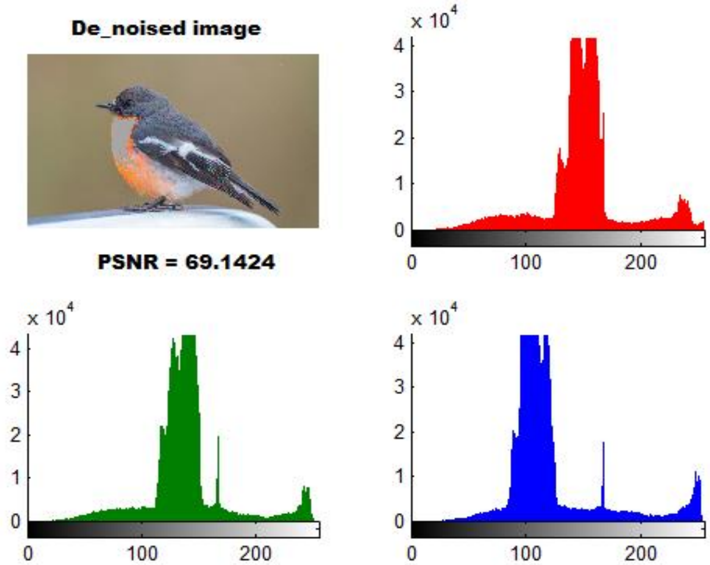

Figure 24: Denoised image

Table 10: Denoising color image with size= 6119256 bytes

NR %	MSE	PSNR
0.5	0.4154	119.6114
1	0.5102	117.5555
2	0.6990	114.4063
3	0.8815	112.0863
4	1.0901	109.9621
5	1.2881	108.2938
10	2.3663(see figures 25, 26)	102.2122
30	7.5040	90.6709
50	15.1500	83.6453
80	40.7579	73.7488
90	64.6047	69.1424

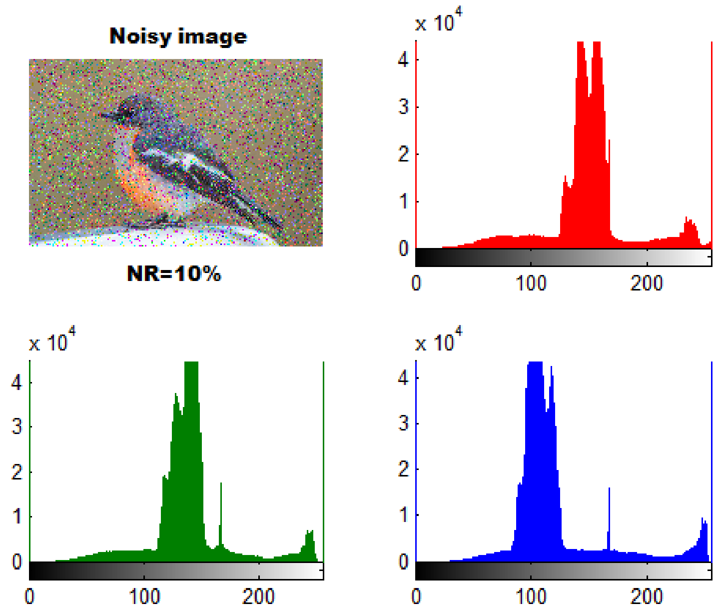

Figure 25: Noisy image with NR=10%

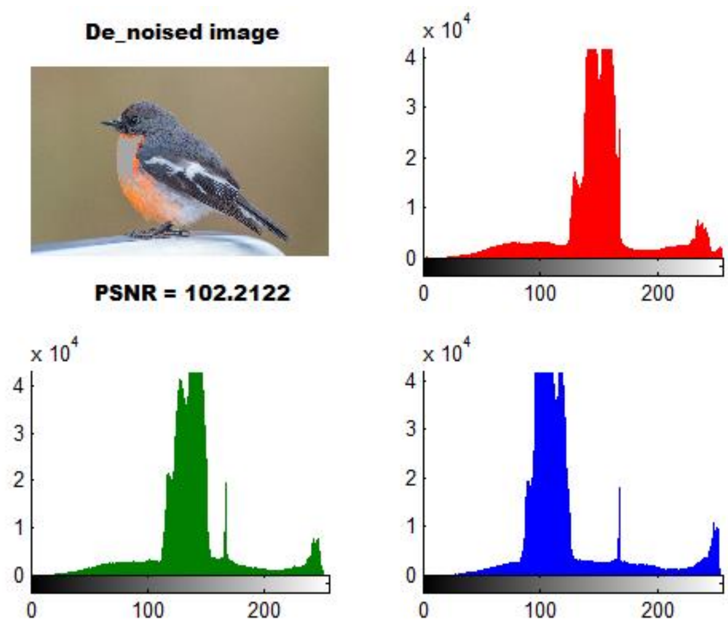

Figure 26: Denoised image in figure 25

Conclusion

A simple and highly efficient method of reducing salt and pepper noise was introduced, tested and implemented using various images affected by SAPN with various values o NR. The obtained experimental results showed that the proposed method can efficiently deal with SAPN with low and high NR. The results were compared with median filter results and it was shown that the proposed filter made good improvements in the filtering efficiency.

The well known digital filters (DBPTGMF, (MDBPTGMF), (AWMF) (AAMF), were also implemented, the implementation results of these filters were also compared with the proposed filter results and it was shown that the proposed filter provided better efficiency by enhancing the values of MSE and PSNR for various images with various NRs.

The proposed filter only treat the infected by SAPN pixels, this was done using special created check matrices (RWs) and processing matrices (PWs), several matrices were created and used. The number of these matrices depends on the selected padding factor and the best results were achieved when using a 5 by 5 padding factor.

The proposed filter can be easily used to denoised infected with SAPN color images, and it was shown that the proposed filter has an excellent performance especially when the noise has a high NR.

References

[1] R. C. Gonzalez and R. E. Woods, Digital Image Processing, Addison Wesley, 2nd edition, 1992.

[2] T. A. Nodes and N. C. Gallagher, "Median filters: some modifications and their properties," IEEE Trans. Acoustics, Speech and Signal Processing, vol. 30, no.5, pp. 739-746, Oct. 1982.

[3] R. Yang, L. Lin, M. Gabbouj, J. Astola, and Y. Neuvo, "Optimal weighted median filters under structural constrains," IEEE Trans. Signal Processing, vol. 43, no.3, pp. 591-604, Mar. 1995.

[4] J. B. Bednar and T. K. Watt, "Alpha-trimmed means and their relationship to median filter," IEEE Trans. Acoustics, Speech and Signal Processing, vol. 32, no.1, pp. 145-153, Jan. 1984.

[5] K. S. Srinivasan and D. Ebenezer, "A new fast and efficient decision based algorithm for removal of high density impulse noise," IEEE Signal Process. Lett., vol. 14, no. 6, pp. 1506-1516, Jun. 2006.

[6] K. Aiswarya, V. Jayaraj, and D. Ebenezer, " A new and efficient algorithm for the removal of high density salt and pepper noise in images and videos," in Second Int. Conf. Computer Modeling and Simulation,2010, pp. 409- 413

[7] S. Esakkirajan, T. Veerakumar, A. N. Subramanyam, and C. H. PremChand, "Removal of high density salt and pepper noise through modified decision base unsymmetric trimmed median filter," IEEE Signal process. Lett,vol. 18, pp. 287-290, May. 2011.

[8] M.T. Raza, And S. Sawant, "High density salt and pepper noise removal through decision based partial trimmed global mean filter," Engineering (NUiCONE), 2012 Nirma University International Conference on, pp.1-5, IEEE, Dec. 2012

[9] A. Dash and S. K. Sathua, "High Density Noise Removal By Using Cascading Algorithms," 2015 Fifth International Conference on Advanced Computing & Communication Technologies, pp. 96-101, IEEE Computer Society, Feb. 2015

[10] Sujaya Kumar Sathua , Arabinda Dash , Aishwaryarani Behera , Removal of Salt and Pepper noise from Gray-Scale and Color Images: An Adaptive Approach, International Journal of Computer Science Trends and Technology (IJCST) – Volume 5 Issue 1, Jan – Feb 2017.

[11] P. Zhang and F. Li, "A New Adaptive Weighted Mean Filter for Removing Salt and Pepper Noise," IEEE Signal Process. Lett., vol. 21, no. 10, pp. 1280-1283, Oct. 2014.

[12] M. Abu-Faraj, and Z. Alqadi, "Image Encryption using Variable Length Blocks and Variable Length Private Key," International Journal of Computer Science and Mobile Computing (IJCSMC), vol. 11, Iss. 3, pp. 138-151, 2022.

[13] M. Abu-Faraj, A. Al-Hyari, and Z. Alqadi, "A Dual Approach for Audio Cryptography," Journal of Southwest Jiaotong University, vol. 57, no. 1, pp. 24-33, 2022.

[14] M. Abu-Faraj, A. Al-Hyari, and Z. Alqadi, "Complex Matrix Private Key to Enhance the Security Level of Image Cryptography," Symmetry, vol. 14, Iss. 4, pp. 664-678, 2022.

[15] M. Abu-Faraj, K. Aldebei, and Z. Alqadi, "Simple, Efficient, Highly Secure, and Multiple Pur- posed Method on Data Cryptography," Traitement du Signal, vol. 39, no. 1, pp. 173-178, 2022.

[16] M. Abu-Faraj, Khaled Aldebe, and Z. Alqadi, "Deep Machine Learning to Enhance ANN Per- formance: Fingerprint Classifier Case Study," Journal of Southwest Jiaotong University, vol. 56, no. 6 , pp. 685-694, 2021.

[17] M. Abu-Faraj, Z. Alqadi, and K. Aldebei, "Comparative Analysis of Fingerprint Features Ex- traction Methods," Journal of Hunan University Natural Sciences, vol. 48, iss. 12, pp. 177-182, 2021.

[18] M. Abu-Faraj, and Z. Alqadi, “Rounds Reduction and Blocks Controlling to Enhance the Performance of Standard Method of Data Cryptography,” International Journal of Computer Science and Network Security (IJCSNS), vol. 21, no. 12, pp. 648-656, 2021.

[19] M. Abu-Faraj, and Z. Alqadi, “Improving the Efficiency and Scalability of Standard Meth- ods for Data Cryptography,” International Journal of Computer Science and Network Security (IJCSNS), vol. 21, no.12, pp. 451-458, 2021.

[20] Majed O Al-Dwairi, Ziad A Alqadi, Amjad A Abujazar, Rushdi Abu Zneit, Optimized true-color image processing, World Applied Sciences Journal, vol. 8, issue 10, 2010, pp. 1175-1182.

[21] Jamil Al Azzeh, Hussein Alhatamleh, Ziad A Alqadi, Mohammad Khalil Abuzalata, Creating a Color Map be used to Convert a Gray Image to Color Image, International Journal of Computer Applications, vol. 153, issue 2, 2016, pp. 31-34.

[22] Qazem Jaber Ziad Alqadi, Jamil azza, Statistical analysis of methods used to enhance color image histogram, XX International scientific and technical conference, 2017.

[23] Bassam Subaih Ziad Alqadi, Hamdan Mazen, A Methodology to Analyze Objects in Digital Image using Matlab, International Journal of Computer Science & Mobile Computing, vol. 5, issue 11, 2016,pp. 21-28.

[24] Mazen A.Hamdan Bassam M.Subaih, Prof. Ziad A. Alqadi, Extracting Isolated Words from an Image of Text, International Journal of Computer Science & Mobile Computing, vol. 5, issue 11, 2016, pp. 29-36.

[25] Dr. Amjad Hindi, Dr. Majed Omar Dwairi, Prof. Ziad Alqadi, Analysis of Procedures used to build an Optimal Fingerprint Recognition `System, International Journal of Computer Science and Mobile Computing, vol. 9, issue 2, 2020, pp. 21 –37.

[26] Aws AlQaisi, Mokhled AlTarawneh, Ziad A. Alqadi, Ahmad A. Sharadqah, Analysis of Color Image Features Extraction using Texture Methods, TELKOMNIKA, vol. 17, issue 3, 2019, pp. 1220-1225.

[27] Ahmad Sharadqh Naseem Asad, Ismail Shayeb, Qazem Jaber, Belal Ayyoub, Ziad Alqadi, Creating a Stable and Fixed Features Array for Digital Color Image, IJCSMC, vol. 8, issue 8, 2019, pp. 50-56.

[28] Ziad Alqadi, Dr. Mohammad S. Khrisat, Dr. Amjad Hindi,Dr.Majed Omar Dwairi, VALUABLE WAVELET PACKET INFORMATION TO ANALYZE COLOR IMAGES FEATURES, International Journal of Current Advanced Research, vol. 9, issue 2, 2020, pp. 2019.

[29] Ziad AlQadi, M Elsayyed Hussein, Window Averaging Method to Create a Feature Victor for RGB Color Image, International Journal of Computer Science and Mobile Computing, vol. 6, issue 2, 2017,pp. 60-66.

[30] K Matrouk, A Al-Hasanat, H Alasha'ary, Z Al-Qadi, H Al-Shalabi, World Applied Sciences Journal 31 (10), 1767-1771, 2014.

[31] Majed O. Al-Dwairi, Amjad Y. Hendi, Mohamed S. Soliman, Ziad A.A. Alqadi, A new method for voice signal features creation, International Journal of Electrical and Computer Engineering (IJECE), vol. 9, issue 5, pp. 4092-4098, 2019.

[32] Saleh Khawatreh, Belal Ayyoub, Ashraf Abu-Ein, Ziad Alqadi, A Novel Methodology to Extract Voice Signal Features, International Journal of Computer Applications, vol. 179, issue 2, pp. 40-43, 2018.

[33] Ayman Al-Rawashdeh, Ziad Al-Qadi, using wave equation to extract digital signal features, Engineering, Technology & Applied Science Research, vol. 8, issue 4, pp. 1356-1359, 2018.

[34] Jihad Nadir, Ashraf Abu Ein, Ziad Alqadi, A Technique to Encrypt-decrypt Stereo Wave File, International Journal of Computer and Information Technology, vol. 5, issue 5, pp. 465-470, 2016.

[35] Jihad Nader Ismail Shayeb, Ziad Alqadi, Jihad Nader, Analysis of digital voice features extraction methods, International Journal of Educational Research and Development, vol. 1, issue 4, pp. 49-55, 2019.

[36] Belal Zahran Rashad J Rasras, Ziad Alqadi, Mutaz Rasmi Abu Sara, B Zahran, developing new Multilevel security algorithm for data encryption-decryption (MLS_ED), International Journal of Advanced Trends in Computer Science and Engineering, vol. 8, issue 6, pp. 3228-3235, 2019.

[37] Naseem Asad, Ismail Shayeb, Qazem Jaber, Belal Ayyoub, Ziad Alqadi, Ahmad Sharadqh, creating a Stable and Fixed Features Array for Digital Color Image, IJCSMC, Vol. 8, Issue. 8, August 2019, pg.50 – 62.

[38] Ziad A. Alqadi, Majed O. Al-Dwairi, Amjad A. Abu Jazar and Rushdi Abu Zneit, Optimized True-RGB color Image Processing, World Applied Sciences Journal 8 (10): 1175-1182, ISSN 1818-4952, 2010.

[39] A. A. Moustafa, Z. A. Alqadi, “Color Image Reconstruction Using a New R'G'I Model”, Journal of Computer Science, Vol.5, No. 4, pp. 250-254, 2009.

[40] Prof. Ziad A.A. Alqadi, Prof. Mohammed K. Abu Zalata, Ghazi M. Qaryouti, Comparative Analysis of Color Image Steganography, JCSMC, Vol.5, Issue. 11, November 2016, pg.37–43.

[41] Ziad A. Alqadi Mua'ad M. Abu-Faraj, Rounds Reduction and Blocks Controlling to Enhance the Performance of Standard Method of Data Cryptography, International Journal of Computer Science and Network Security, vol. 21, issue 12, pp. 648-656, 2021.

[42] Ziad Alqadi Mua'ad Abu-Faraj, Khaled Aldebei, DEEP MACHINE LEARNING TO ENHANCE ANN PERFORMANCE: FINGERPRINT CLASSIFIER CASE STUDY, JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY, vol. 56, issue 6, pp. 686-694, 2021.

[43] Ziad A. Alqadi Mua'ad M. Abu-Faraj, Improving the Efficiency and Scalability of Standard Methods for Data Cryptography, International Journal of Computer Science and Network Security, vol. 21, issue 12, pp. 451-458, 2021.

[44] Mua'ad M. Abu-Faraj Prof. Ziad Alqadi, Using Highly Secure Data Encryption Method for Text File Cryptography, International Journal of Computer Science and Network Security, vol. 20, issue 11, pp. 53-60, 2021.