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. 3, March 2022, pg.1 – 16

Two Ways to Improve Average and Median Filters

Dr. Mahammad Abu Zalata*; Dr. Musbah J. Aqel; Dr. Ziad Alqadi***

*Al Balqa Applied University

**Arab University College of Technology

Jordan-Amman

DOI: https://doi.org/10.47760/ijcsmc.2022.v11i03.001

Abstract: Colored digital images are exposed to various types of noise, the most important of which is salt and pepper noise, which negatively affects the clarity of the image in addition to the negative effects on its characteristics, which calls for providing an effective method that mitigates the negative effects of noise as much as possible. The two filters average and median are considered two of the best filters used to remove salt and pepper noise or mitigate the negative effects of this noise, especially if the noise density is low. However, when this density rises, these filters become ineffective in dealing with the noise.

In this paper research we will introduce two ways of improving the operations of average and median filters, these improved filters will be tested and compared with the standard average and median filters, it will be shown how the improvements will enhance the value of the quality parameters MSE and PSNR, some recommendation will be raised to show when and how to use each of the improvement ways.

Keywords: Average filter, median filter, mask, salt and pepper noise, noise density, MSE, PSNR.

Introduction

The digital color image 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 [1-5]. Digital color image can be represented by 3 2D matrices (one 2D matrix for each color: red, green and blue) as shown in figure 1 [20-25]. Each matrix can be extracted and treated separately, and the processed colors matrices can be combined to form a processed digital color image [6-12].

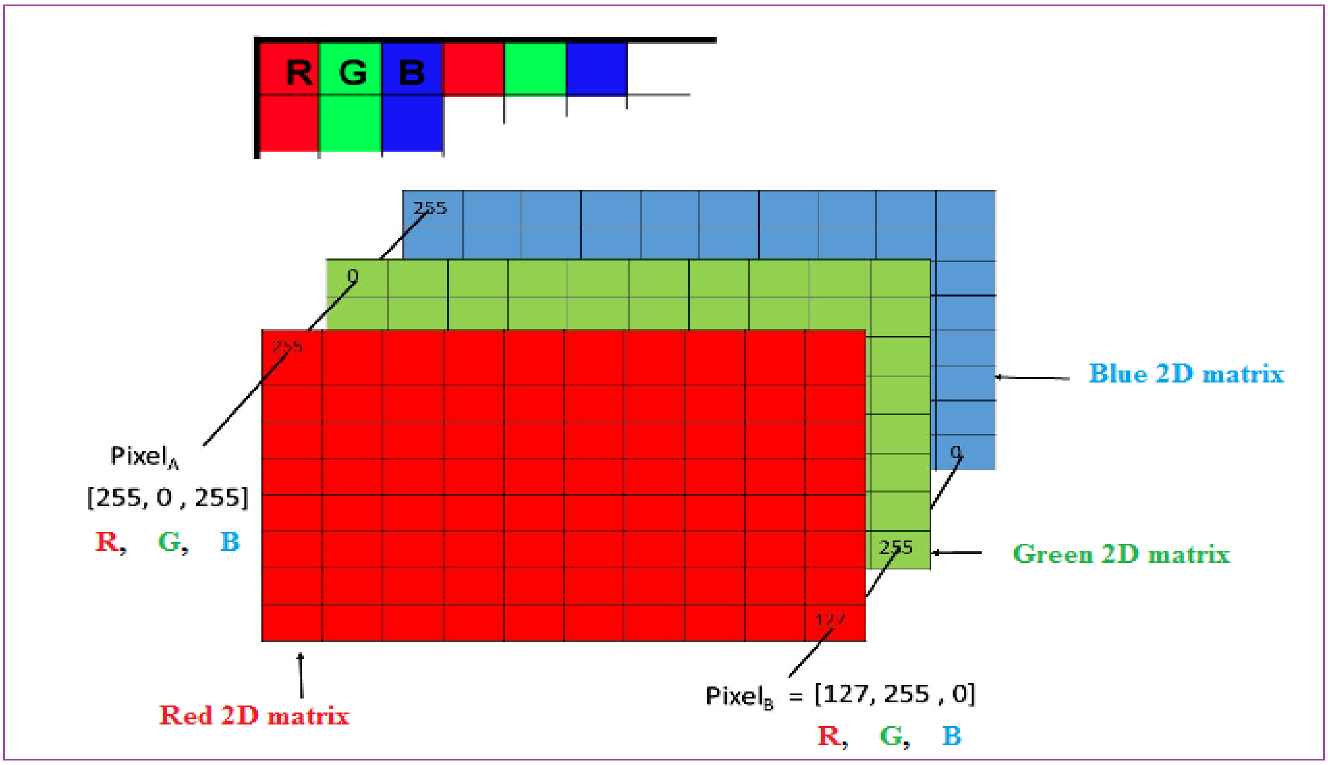

Figure 1: Color image representation

Salt and pepper noise is one of the most popular noises that can affect the color image making it unclear, this noise changes some pixel's values to 0 (pepper) or to 255 (salt), the negative effects caused by this noise depends on the noise density which is equal the number of affected pixels divided by the total pixel in the image, figure 2 shows how the negative effects will be increased when increasing noise density [13-19].

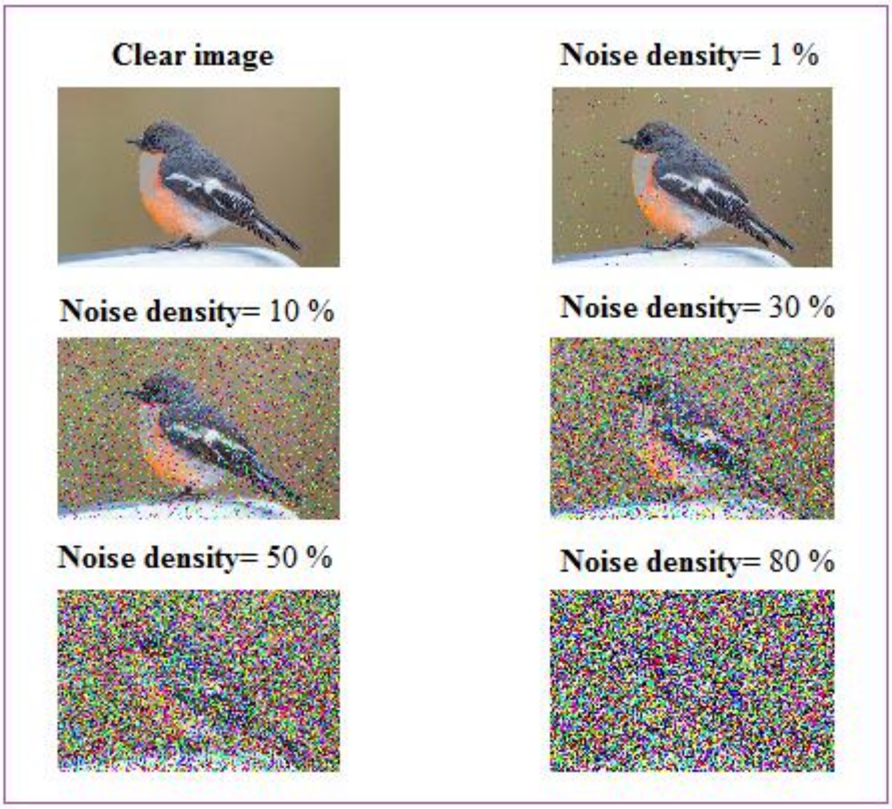

Figure 2: Effects of increasing noise density

The quality of the filter operation can be measured by mean square error (MSE) between a source and denoised image, or/and by peak signal to noise ratio (PSNR), the quality parameters can be calculated using equations 1 and 2 shown below [30-40]:

MSE of x channel

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

Total MSE

$$MSE_t = MSE_R + MSE_G + MSE_B$$

Calculate PSNR

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

The mean-square error (MSE) and the peak signal-to-noise ratio (PSNR) are used to compare image compression quality [26-30]. The MSE represents the cumulative squared error between the denoised and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error, and hence the higher quality, and the higher the value of PSNR the higher the quality level, and here the effective filter used to reduce the salt and pepper noise must minimize the value of MSE and at the same time maximize the value of PSNR, and acceptable values for the PSNR are above 50 dB [20-25].

Related works

Many filters such as Gaussian, Sobel, Prewitt, Laplacian, Unsharp, log, median and average filter are used to reduce salt and pepper noise. In [43] it was shown that all these filters except average and median filter have poor utilization and the calculated quality parameters are not acceptable specially if the noise density is high, so we will focus in this paper research on average and median filters because they have better performance comparing with other filters [41-43].

Median filter operates on each pixel in the noisy image [41], [42]; figure 3 illustrates an example of how this filter operates.

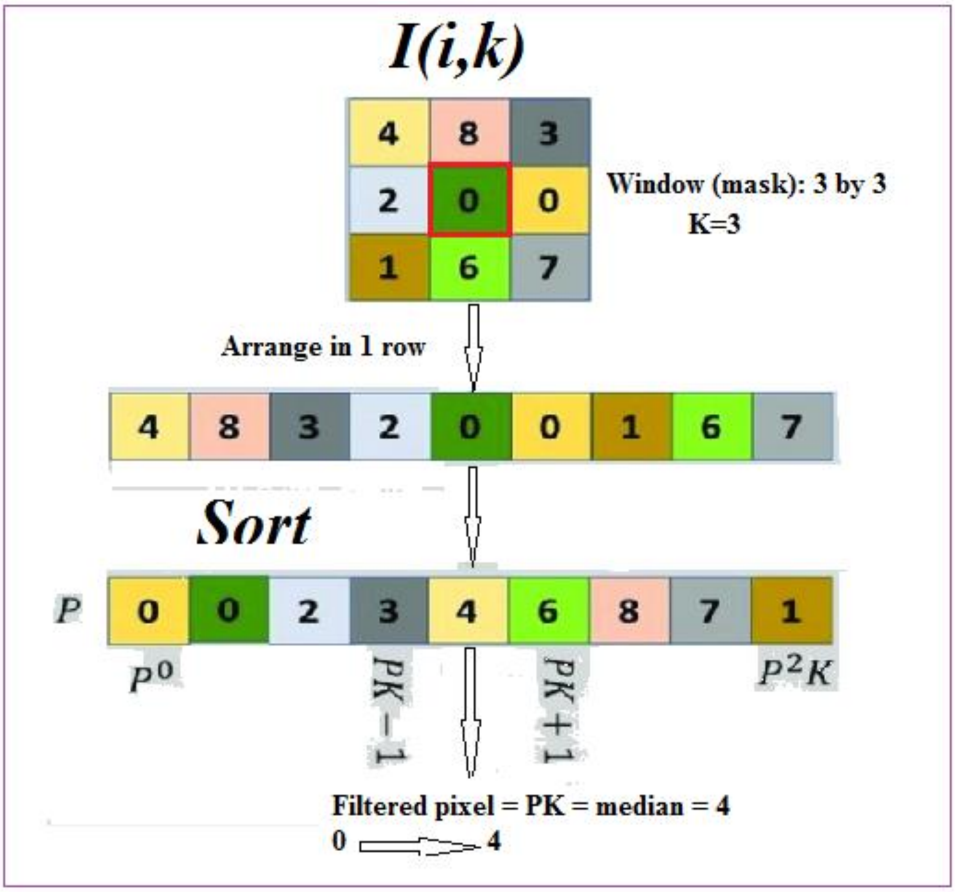

Figure 3: Median filter operations

Average filter is also operating on each pixel in the noisy image, it uses a mask to be convoluted with the noisy image to produce a denoised image, figure 4 shows an example of how this filter operates [41-43].

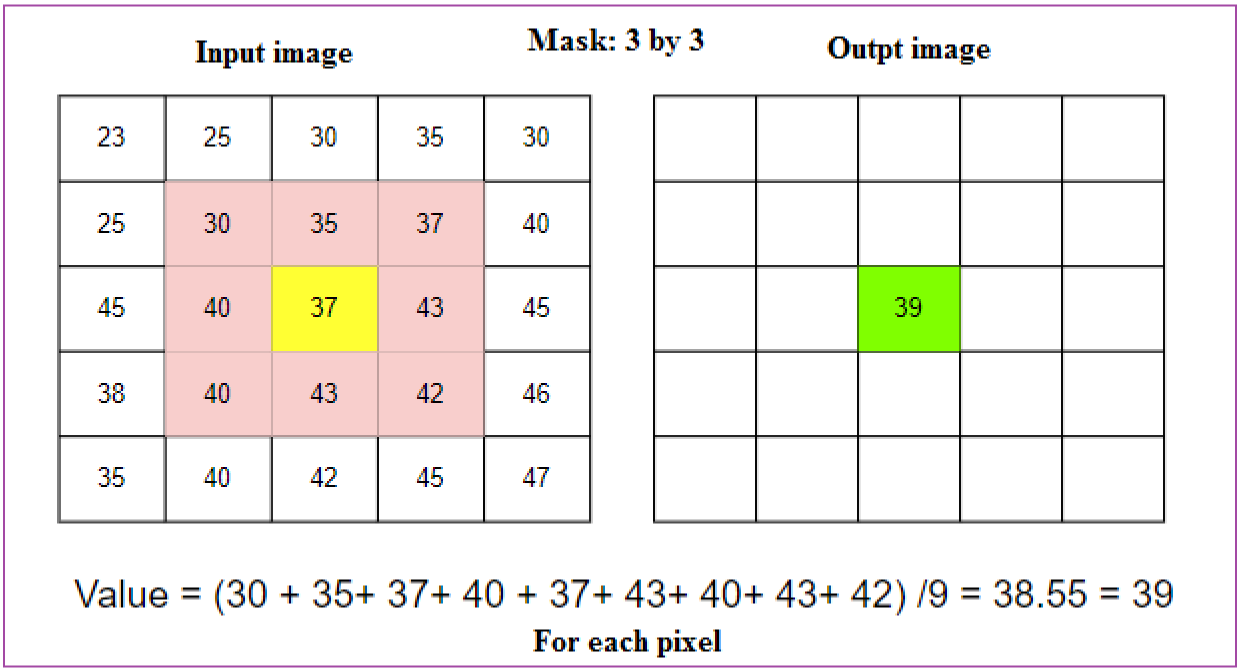

Figure 4: Average filter operations

Median and average filters can be used to reduce the effects of salt and pepper noise when the noise density is low, here median filter gives better results when the noise density is low, this is shown in figures 5 and 6.

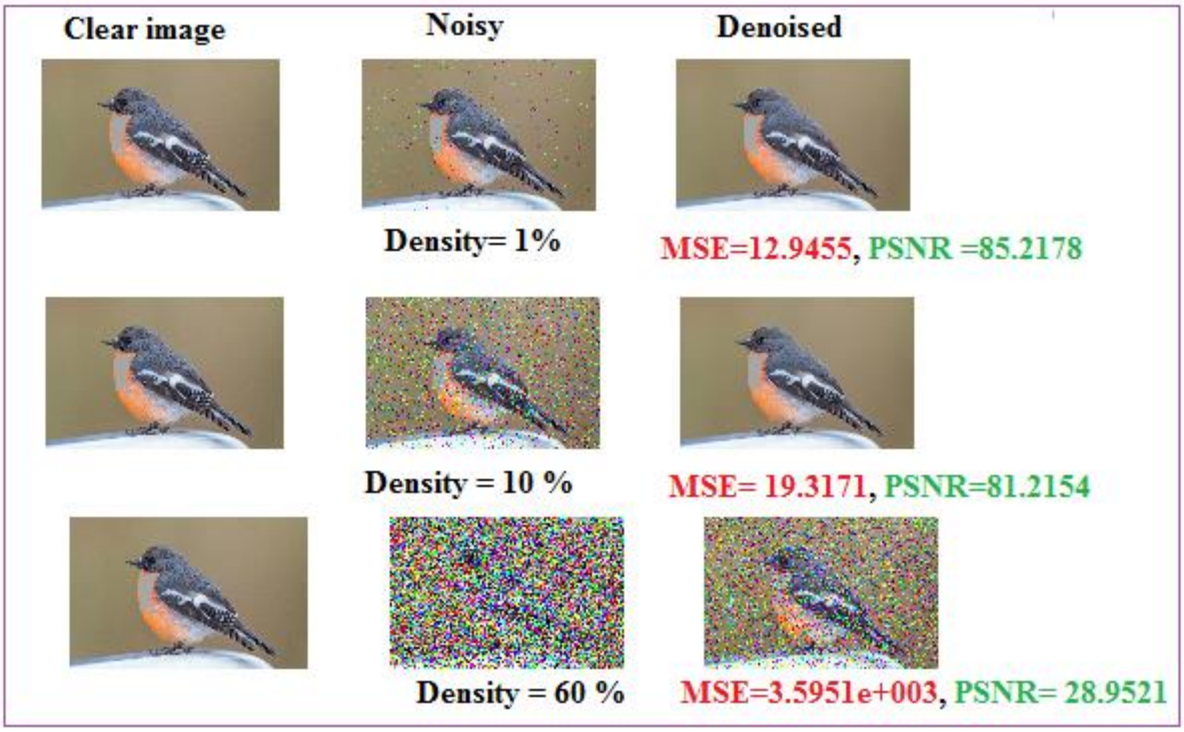

Figure 5: Denoising using median filter

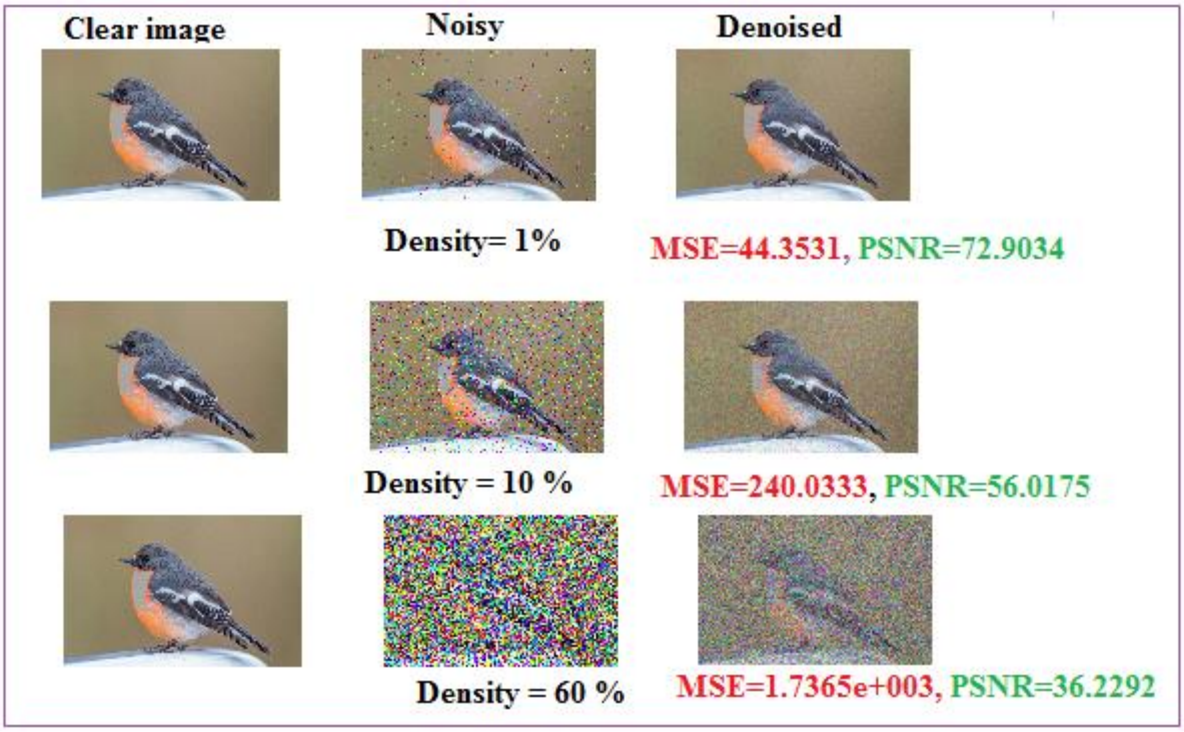

Figure 6: Denoising using average filter

The proposed method

The median/average filter can be implemented applying the following algorithm:

Input:

Noisy color image.

Output:

Denoised color image.

Operations:

- *Extract each color from the noisy color image.*
- *Apply median or average filter to denoised each color.*
- *Combine the three denoised colors to form the denoised color image.*

This algorithm can be improved to enhance the values of MSE and PSNR; the improved 1 algorithm can be implemented as follows:

Improved 1 algorithm:

Input:

Noisy color image>

Output:

Denoised color image.

Operations:

- *Extract the color matrices.*

- *For each color matrix do the following:*

- *For each pixel do the following.*

- If the pixel not equal zero, or the pixel not equal 255 move this pixel from the noisy image to the denoised image, otherwise apply filtering for this pixel.

- Combine the three matrices to form the denoised color image.

Improved 2 algorithm:

This algorithm can be implemented applying the following:

Input:

Noisy color image.

Output:

Denoised color image.

Operations:

- Extract each color matrix.
- For each color matrix (A).
- Create a logical matrix B matrix using A, as shown in figure 7:

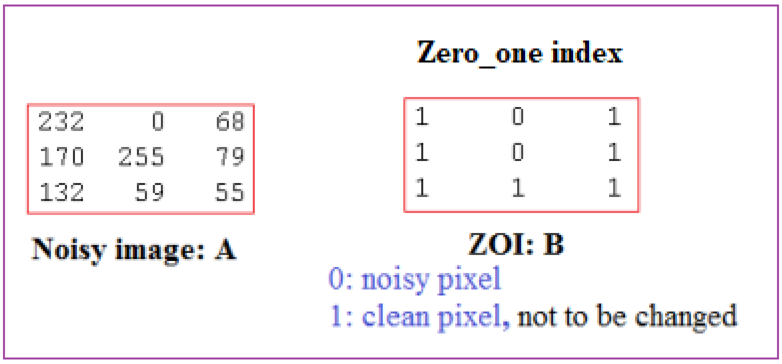

Figure 7: Mask index

- *Create padding matrix PA and padding index matrix PB matrices based on the mask size as shown in figures 8 and 9:*

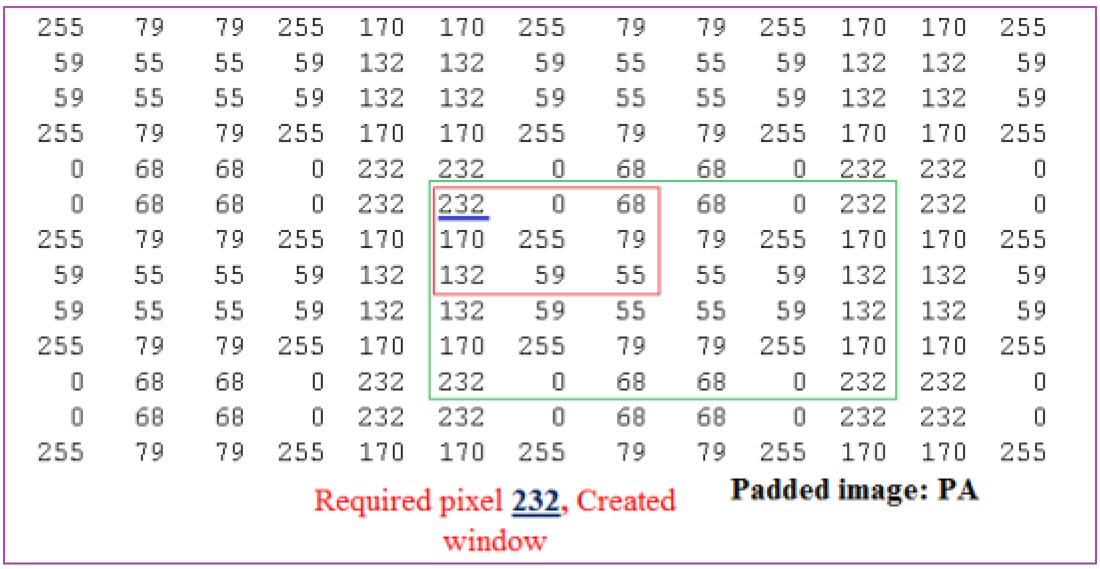

Figure 8: Padding matrix PA

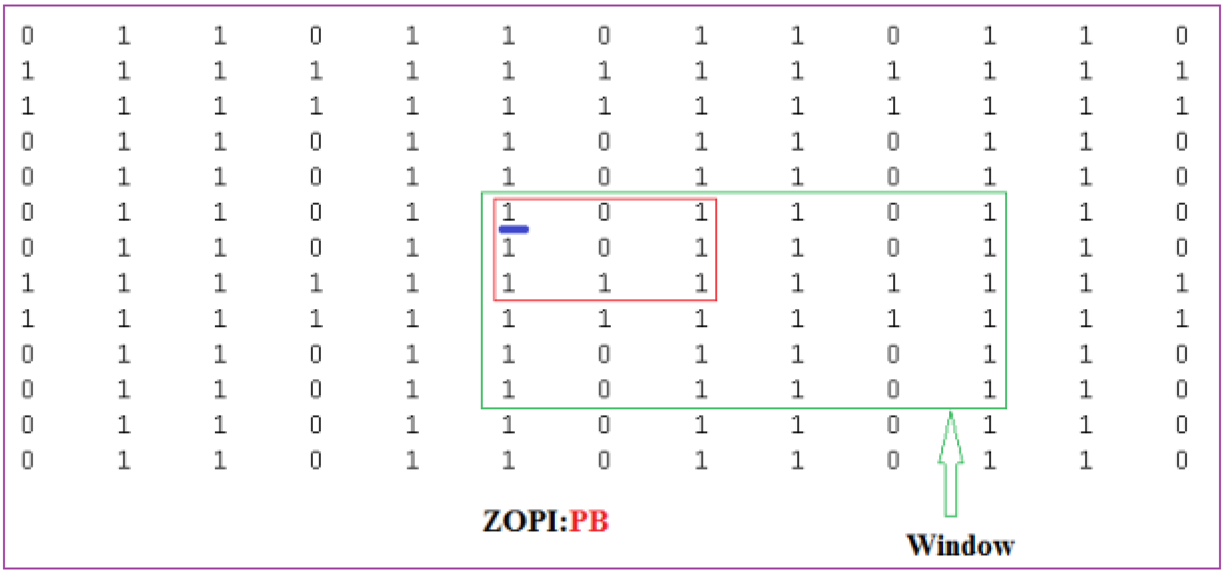

Figure 9: Padding index matrix PB

- *For each pixel in A, compare the associated pixel in B with 1, if equal 1 leave the pixel in A without change and proceed to the next pixel, else proceed to the next step.*
- *If the sum of elements in the window of matrix PB equal zero leave the pixel in A without change and proceed to the next pixel in A, else proceed to the next step.*
- *Find the median value in the window in matrix PA excluding the elements with zero and 255 values.*
- *Replace the pixel in A with the median value.*
- *Combine the matrices A of the tree colors to form the denoised color image.*

Below are examples of the improved 2 algorithm:

Example 1:
The pixel under processing is not a noisy pixel (greater than zero and less than 255) (apply improvement 1), see figure 10:

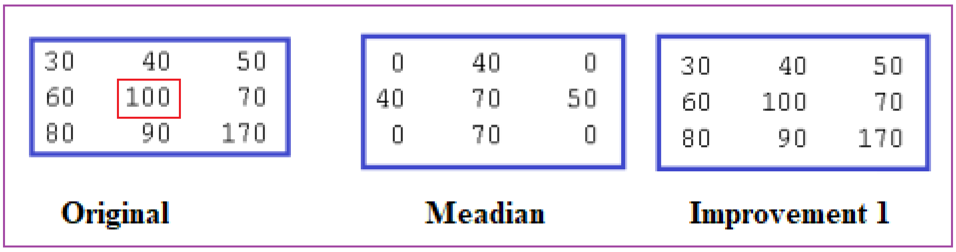

Figure 10: Improvement 1 example

Example 2:

Keep the pixel without change, the pixel under processing is not a noisy pixel and it is surrounded by zero noisy pixels (see figure 11):

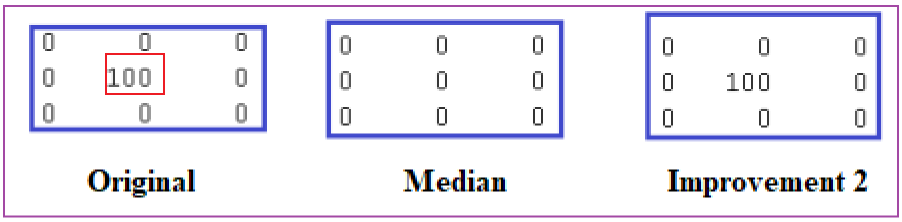

Figure 11: Keep the pixel without change, (improvement 2)

Example 3:

Keep the pixel without change, the pixel under processing is not a noisy pixel and it is surrounded by noisy pixels with value =255 (improvement 2) (see figure 12):

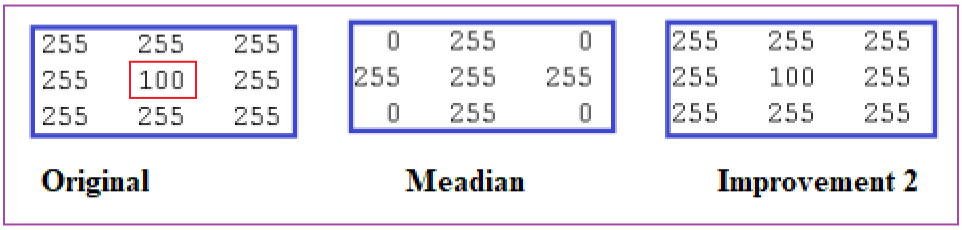

Figure 12: keep the pixel without change, (improvement 2)

Example 4:

For the created window, and if the condition in figure 13 is satisfied then the pixel value must equal the mean (average)

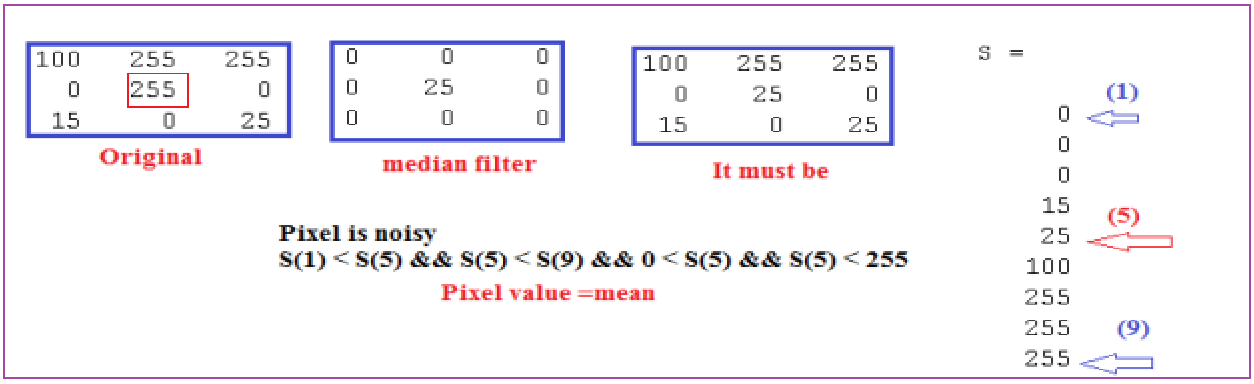

Figure 13: Change the pixel value (improvement 2)

Example 5:

For the created window, and if median (average) value =0 (see figure 14), keep the pixel value without change.

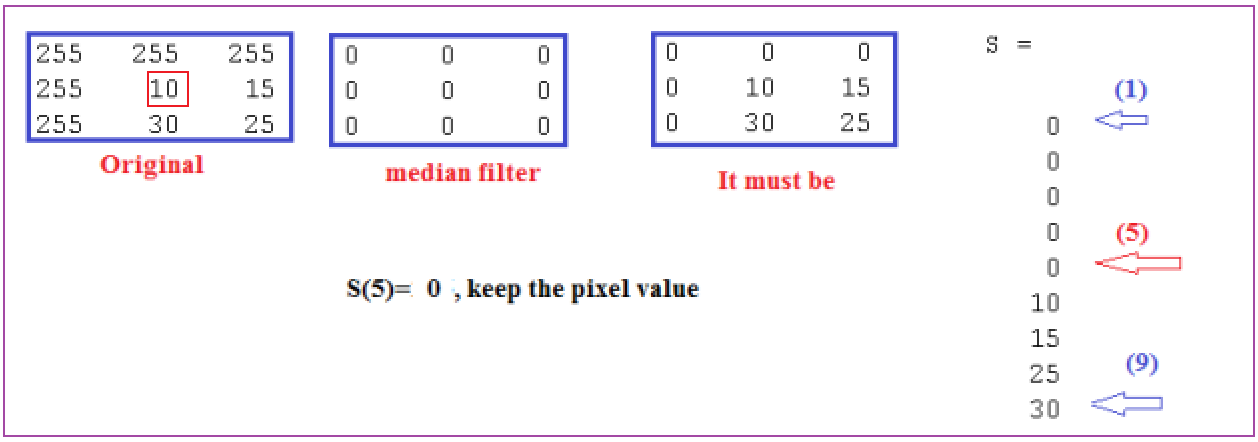

Figure 14: Keep the pixel without change (Improvement 2)

Example 6:

For the Created window, and if median (average) value =255 (see figure 15), keep the pixel value without change.

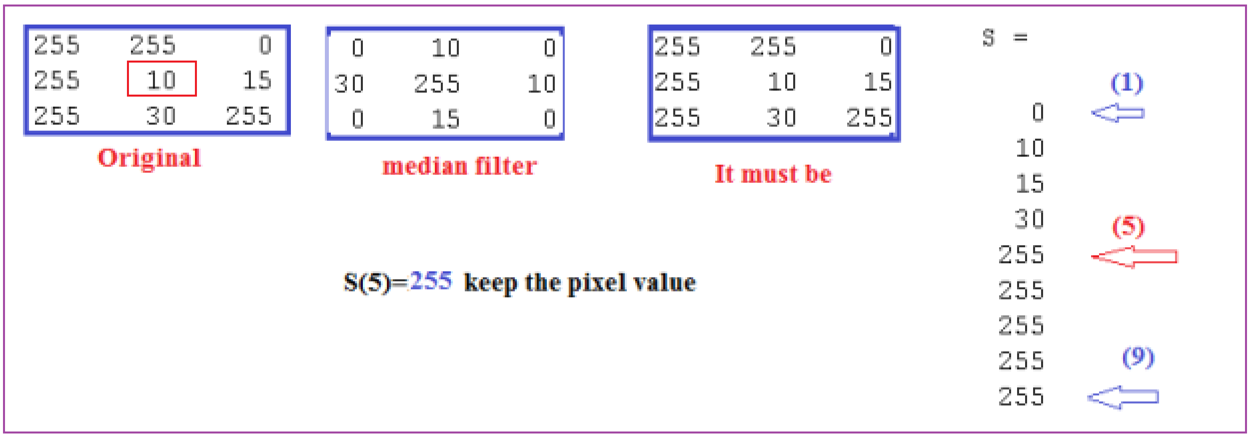

Figure 15: Keep the pixel without change (Improvement 2)

Implementation and experimental results

The proposed two ways were implemented using color image with various noise densities, figures 16, 17 and 18 show an output examples of the implementation, from these figures we can see the following points:

- The quality parameters values obtained by improvement 2 and using high density noise are better [41-43].
- Increasing the mask size from 3 by 3 to 9 by 9 will decrease the MSE and at the same time increase the value of PSNR making the denoised image closer to the clean color image.
- For high density noises we recommend using improvement 2, while for lower density noises it sufficient to use improvement 2, this will be shown in the next shown tables.

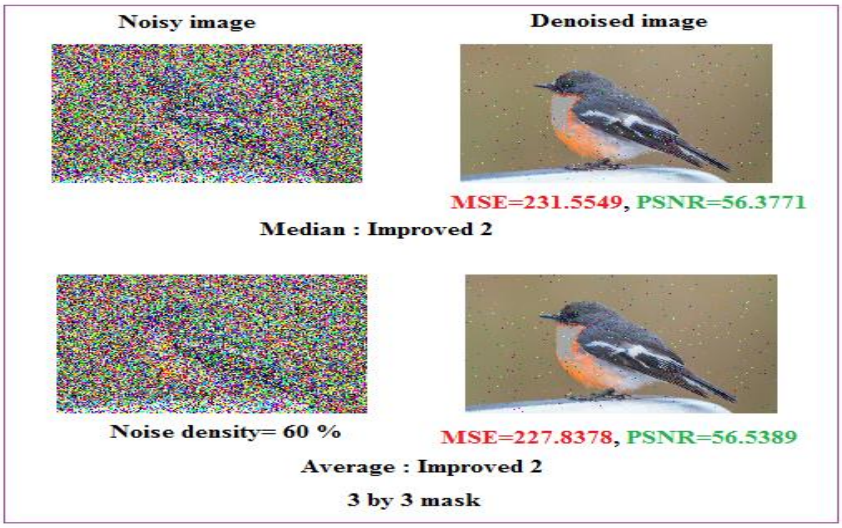

Figure 16: Outputs using improvement 2

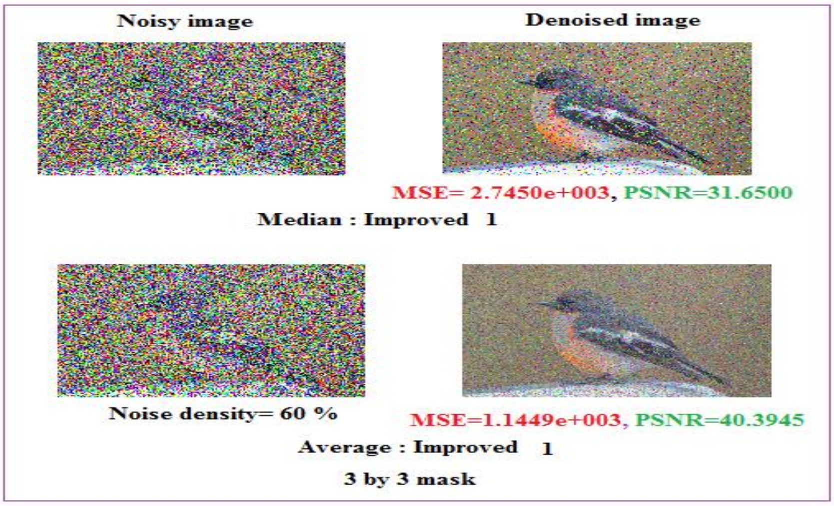

Figure 17: Outputs using improvement 1

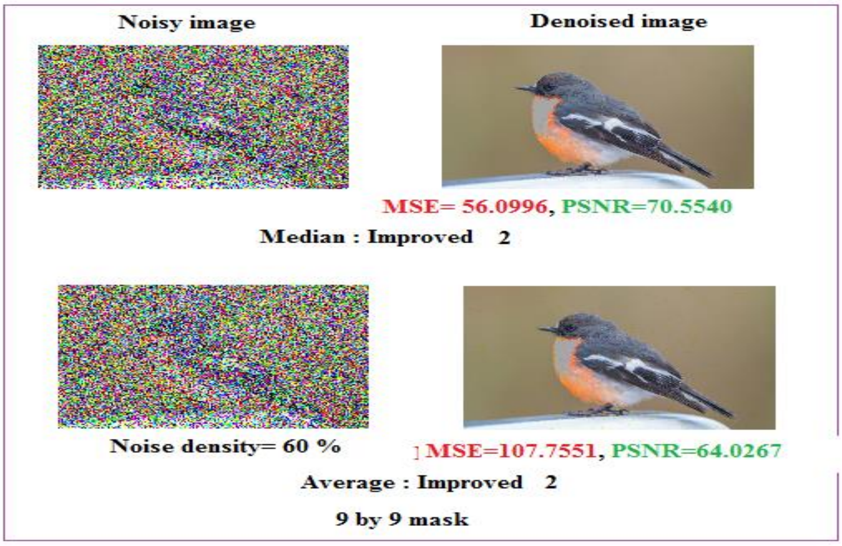

Figure 18: Outputs using improvement 2 (expanded mask)

Noisy image with high densities values were treated using median filter and the two ways of improvements, table 1 shows the obtained experimental results, and figure 19 shows an output example.

Table 1: High density noise reduction using median filter

Noise density %	Median filter		First improvement		Second improvement	
	MSE	PSNR	MSE	PSNR	MSE	PSNR
20	61.2102	69.6821	29.1936	77.0858	17.9880	81.9282
30	240.5453	55.9962	148.4377	60.8236	25.6576	78.3769
40	755.0159	44.5579	507.2030	48.5362	34.2157	75.4984
50	1.8106e+003	35.8109	1.2942e+003	39.1685	42.1170	73.4208
60	3.5967e+003	28.9475	2.7447e+003	31.6510	50.7826	71.5497
70	6.2157e+003	23.4770	5.0372e+003	25.5792	59.8060	69.9142
80	9.5873e+003	19.1433	8.3364e+003	20.5414	69.7358	68.3781
90	1.3568e+004	15.6702	1.2642e+004	16.3771	83.1880	66.6142

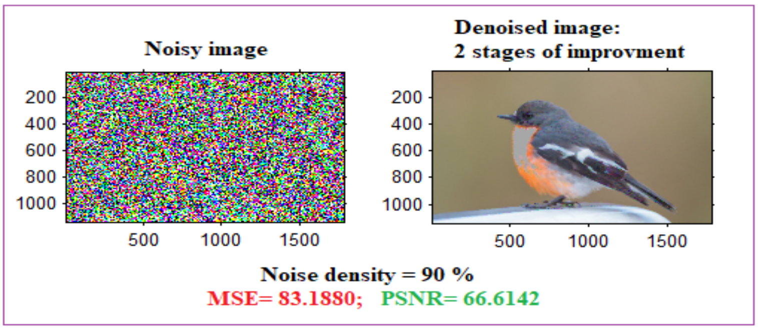

Figure 19: Reduction of high density noise using median filter

The same experiment was repeated using average filter, table 2 shows the obtained results, while figure 20 shows an output example.

Table 2: High density noise reduction using average filter

Noise density %	Average filter		First improvement		Second improvement	
	MSE	PSNR	MSE	PSNR	MSE	PSNR
20	257.6607	55.3088	144.0761	61.1219	18.8691	81.4500
30	406.7541	50.7432	295.5431	53.9371	27.4922	77.6863
40	587.9511	47.0588	506.6721	48.5466	36.0591	74.9737
50	794.1665	44.0523	791.3266	44.0882	44.6033	72.8472
60	1.0323e+003	41.4300	1.1435e+003	40.4070	53.5593	71.0174
70	1.3019e+003	39.1095	1.5761e+003	37.1984	62.5282	69.4691
80	1.6002e+003	37.0463	2.0960e+003	34.3473	71.9359	68.0675
90	1.9308e+003	35.1682	2.7142e+003	31.7629	83.6681	66.5567

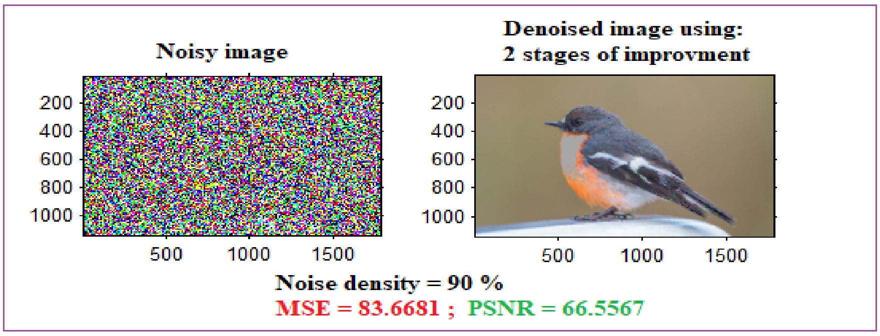

Figure 20: Reduction of high density noise using average filter

Noisy image with low densities values were treated using median filter and the two ways of improvements, table 3 shows the obtained experimental results for median filter, while table 4 shows the obtained results for average filter.

Table 3: Low density noise reduction using median filter

Noise density %	Median filter		First improvement		Second improvement	
	MSE	PSNR	MSE	PSNR	MSE	PSNR
2	13.2697	84.9704	0.5476	116.8482	3.5632	98.1188
4	14.1998	84.2930	1.1508	109.4207	5.1920	94.3540
6	15.4965	83.4191	1.9658	104.0664	6.7398	91.7449
8	17.3800	82.2720	2.9108	100.1410	8.3125	89.6476
10	19.9208	80.9076	4.2725	96.3033	9.8716	87.9287
12	22.6204	79.6368	6.4146	92.2395	11.3596	86.5246
16	35.4070	75.1562	13.4715	84.8195	14.6135	84.0058
19	53.0894	71.1055	25.1055	78.5944	16.6664	82.6913

Table 4: Low density noise reduction using average filter

Noise density %	Average filter		First improvement		Second improvement	
	MSE	PSNR	MSE	PSNR	MSE	PSNR
2	62.2635	69.5115	6.0751	92.7833	3.5768	98.0805
4	79.5076	67.0667	13.8724	84.5263	5.2090	94.3214
6	97.7304	65.0031	23.2278	79.3718	6.9138	91.4901
8	116.7606	63.2240	34.5672	75.3962	8.6842	89.2103
10	137.0803	61.6196	48.3416	72.0423	10.3168	87.4875
12	159.0887	60.1306	62.8458	69.4184	12.0473	85.9369
16	205.5921	57.5663	99.3395	64.8398	15.5437	83.3887
19	243.8175	55.8611	132.6606	61.9473	18.1058	81.8629

From tables 3 and 4 we can see the following points:

- For high density noise reduction, it is recommended to use median filter with two ways of improvements, average filter here gave results which are very closed to median filter.
- For low density noise reduction, it is recommended to use median filter with one way of improvements, this is shown in figures 21 and 22..

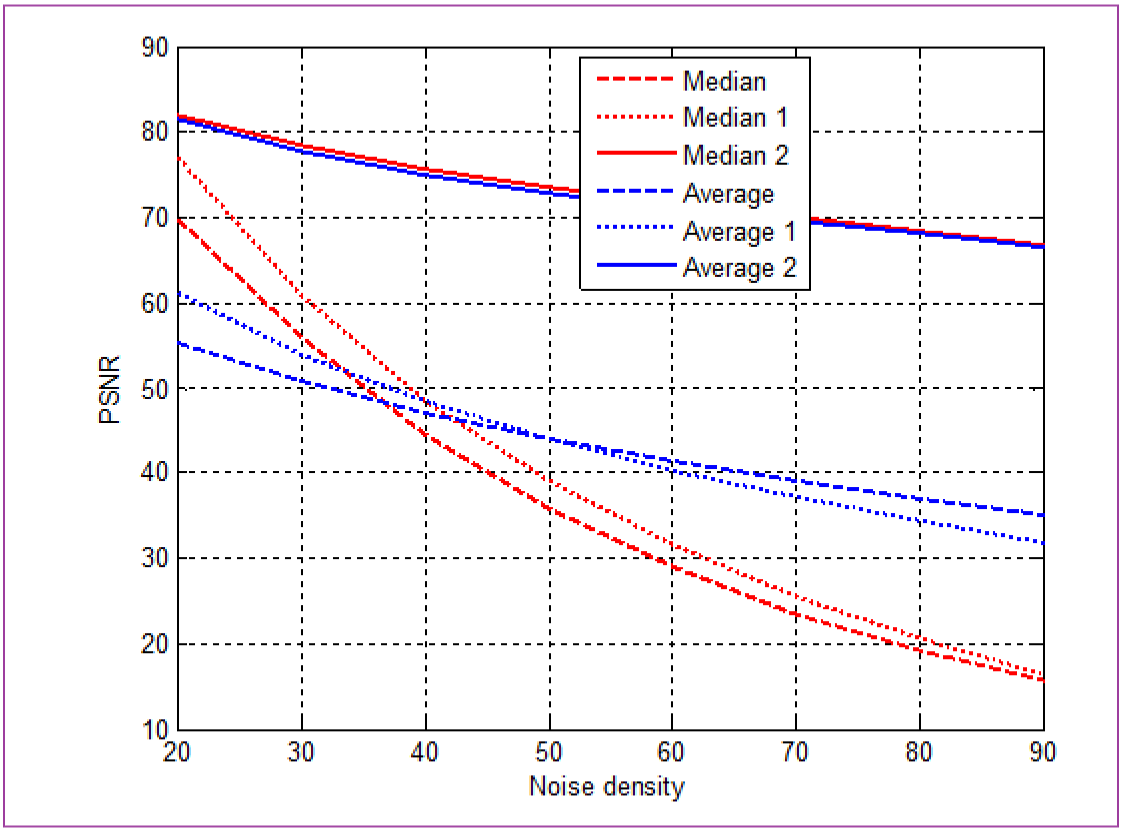

Figure 21: Filters comparisons for high density noise reduction

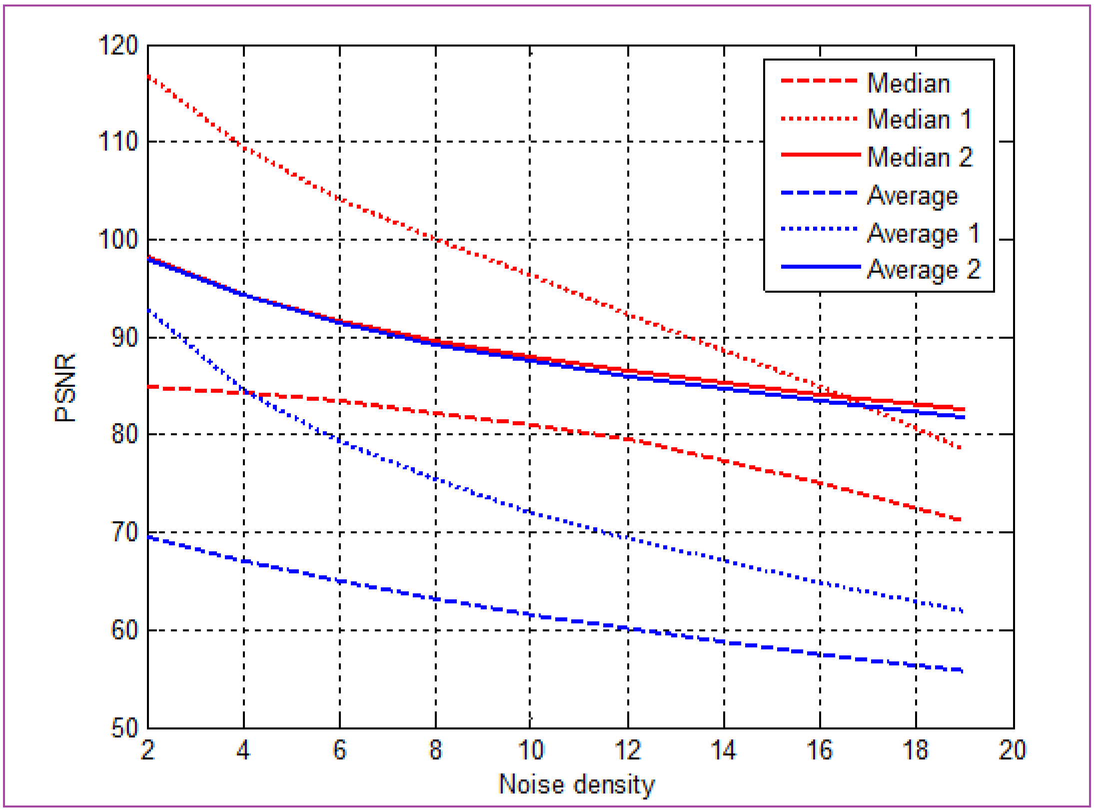

Figure 22: Filters comparisons for low density noise reduction

Mean and average filters apply noise reduction using a mask with a predefined size, different in sizes masks were used to reduce the salt and pepper noise, the filters were implemented using various noise density values, table 5 shows the obtained experimental results.

Table 5: Results using different filters with various mask sizes.

Noise density = 1%				
Mask size	**Median: Improved 2**		**Average: Improved 2**	
	MSE	**PSNR**	**MSE**	**PSNR**
3 by 3	**4.4799**	**95.8292**	**4.1775**	**96.5280**
5 by 5	**3.7994**	**97.4768**	**3.4416**	**98.4660**
7 by 7	**3.1157**	**99.4606**	**2.8432**	**100.3760**
9 by 9	**2.7176**	**100.8279**	**2.4746**	**101.7643**
11 by 11	**2.5411**	**101.4993**	2.4701	101.7825
13 by 13	**2.5887**	**101.3138**	**2.4852**	**101.7217**
Noise density = 10%				
3 by 3	**21.8366**	**79.9894**	**20.3829**	**80.6783**
5 by 5	**16.8368**	**82.5896**	**15.7026**	**83.2870**
7 by 7	**13.2712**	**84.9693**	**12.1467**	**85.8547**
9 by 9	**10.5504**	**87.2636**	**9.9223**	**87.8774**
11 by 11	**9.1784**	**88.6567**	**9.2861**	**88.5401**
13 by 13	**9.2097**	**88.6227**	**9.4843**	**88.3289**
Noise density = 70%				
3 by 3	**652.0105**	**46.0247**	**641.9898**	**46.1795**
5 by 5	**112.8900**	**63.5611**	**104.0381**	**64.3777**
7 by 7	**84.4992**	**66.4578**	**76.5656**	**67.4438**
9 by 9	**66.7093**	**68.8218**	**62.4405**	**69.4831**
11 by 11	**57.4097**	**70.3231**	**56.3838**	**70.5035**
13 by 13	**55.5465**	**70.6531**	**57.9208**	**70.2345**

From table 5 we can see that both average and median filters with 2 improvements gave a results closed to each other, and both of them can be recommended to deal with salt and pepper noise (see figure 23), from the obtained results we can see that the optimal results were obtained when using mask with size 11 by 11.

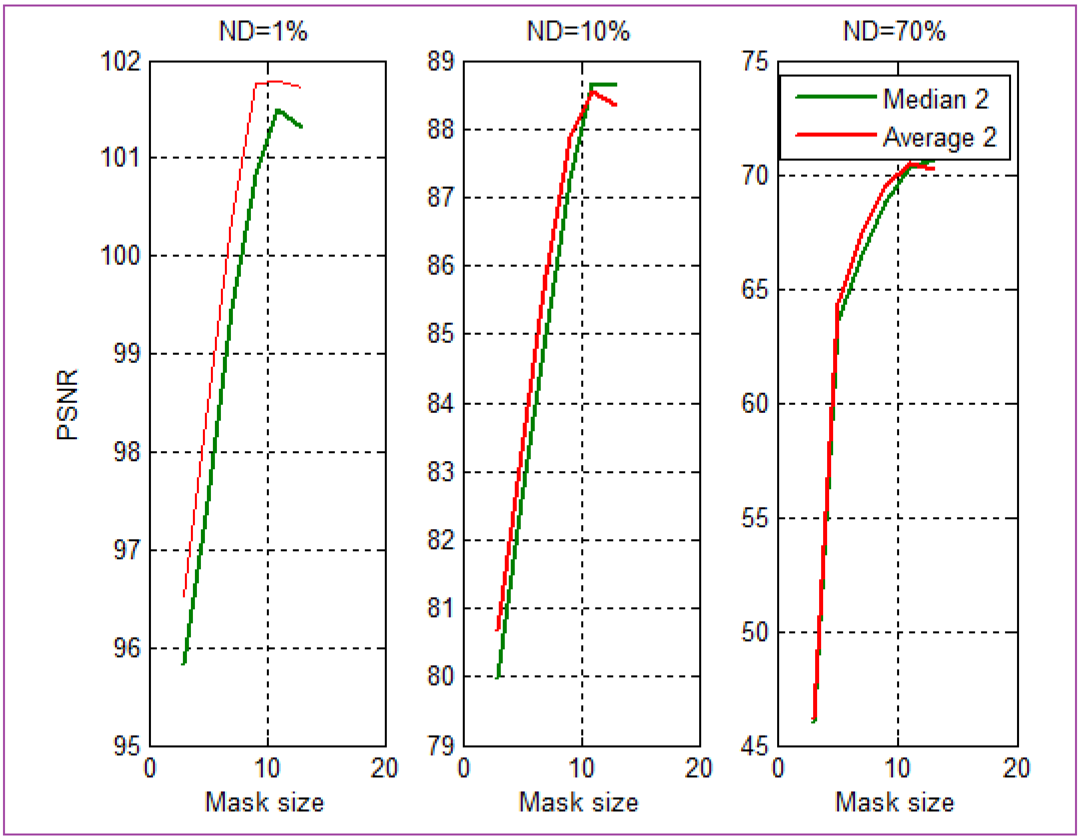

Figure 23; Filters comparisons when increasing the mask size

Conclusion

The median and average filters are used to partially eliminate the effects of salt and pepper noise on color digital images, However, as the noise density increases, these filters become ineffective. The median and average filters were investigated using low and high density noises, the first and second improvements of these filters were implemented and it was shown that these improvements enhanced the values of MSE and PSNR for low and high density noises.

Different masks were used using the suggested improvement and it was show that increasing the mask size will enhance the values of MSE and PSNR, thus provides more noise cleaning., here the best results were obtained when the mask is 11 by 11 matrix. From the obtained results we can recommend median filter with second improvement for high density noise elimination and median filter with first improvement for low noise density elimination.

References

[1]. 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.

[2]. 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, 2018.

[3]. Akram A. Moustafa and Ziad A. Alqadi, A Practical Approach of Selecting the Edge Detector Parameters to Achieve a Good Edge Map of the Gray Image, Journal of Computer Science 5 (5): 355-362, 2009.

[4]. ZA Alqadi, Musbah Aqel, Ibrahiem MM El Emary, Performance analysis and evaluation of parallel matrix multiplication algorithms, World Applied Sciences Journal, vol. 5, issue 2, pp. 211-214, 2008.

[5]. 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.

[6]. Ziad Alqadi, Bilal Zahran, Qazem Jaber, Belal Ayyoub, Jamil Al-Azzeh, Enhancing the Capacity of LSB Method by Introducing LSB2Z Method, International Journal of Computer Science and Mobile Computing, vol. 8, issue 3, pp. 76-90, 2019.

[7]. 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.

[8]. Waheeb, A. and Ziad AlQadi, Gray image reconstruction. Eur. J. Sci. Res., 27: 167-173, 2009.

[9]. 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.

[10]. K Matrouk, A Al-Hasanat, H Alasha'ary, Z. Al-Qadi Al-Shalabi, “Speech fingerprint to identify isolated word person”, World Applied Sciences Journal, Vol. 31, No. 10, pp. 1767-1771, 2014.

[11]. J. Al-Azzeh, B. Zahran, Z. Alqadi, B. Ayyoub, M. Abu-Zaher, “A Novel zero-error method to create a secret tag for an image”, Journal of Theoretical and Applied Information Technology, Vol. 96. No. 13, pp. 4081-4091, 2018.

[12]. 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.

[13]. M. Jose, “Hiding Image in Image Using LSB Insertion Method with Improved Security and Quality”, International Journal of Science and Research, Vol. 3, No. 9, pp. 2281-2284, 2014.

[14]. M. Juneja, P. S. Sandhu, An improved LSB based Steganography with enhanced Security and Embedding/Extraction, 3rd International Conference on Intelligent Computational Systems, Hong Kong China, January 26-27, 2013.

[15]. H. Alasha'ary, K. Matrouk, A. Al-Hasanat, Z. A alqadi, H. Al-Shalabi (2013), Improving Matrix Multiplication Using Parallel Computing, International Journal on Information Technology (I.RE.I.T.) Vol. 1, N. 6 ISSN 2281-2911.

[16]. Bilal Zahran, Ziad Alqadi, Jihad Nader, Ashraf Abu Ein A COMPARISON BETWEEN PARALLEL AND SEGMENTATION METHODS USED FOR IMAGE ENCRYPTION-DECRYPTION, International Journal of Computer Science & Information Technology (IJCSIT) Vol 8, No 5, October 2016.

[17]. Z.A. Alqadi, A. Abu-Jazar (2005), Analysis of Program Methods Used for Optimizing Matrix Multiplication, Journal of Engineering, vol. 15 n. 1, pp. 73-78.

[18]. Jamil Al-Azzeh, Bilal Zahran, Ziad Alqadi, Belal Ayyoub, Muhammed Mesleh: A Novel Based On Image Blocking Method to Encrypt-Decrypt Color JOIV: International Journal on Informatics Visualization, 2019.

[19]. Jamil Al-Azzeh, Bilal Zahran, Ziad Alqadi, Belal Ayyoub and Mazen Abu-Zaher: A Novel Zero-Error Method to Create a Secret Tag for an Image; Journal of Theoretical and Applied Information Technology 15th July 2018.

[20]. Jamil Al Azzeh, Ziad Alqadi Qazem, M. Jabber: Statistical Analysis of Methods Used to Enhanced Color Image Histogram; XX International Scientific and Technical Conference; Russia May 24-26, 2017.

[21]. Jamil Al Azzeh, Hussein Alhatamleh, Ziad A. Alqadi, Mohammad Khalil Abuzalata: Creating a Color Map to be used to Convert a Gray Image to Color Image; International Journal of Computer Applications (0975 – 8887). Volume 153 – No2, November 2016.

[22]. Khaled Matrouk, Abdullah Al- Hasanat, Haitham Alasha'ary, Ziad Al-Qadi, Hasan Al-Shalabi Analysis of Matrix Ziad Alqadi et al, International Journal of Computer Science and Mobile Computing, Vol.8 Issue.3, March- 2019, pg. 76-90.

[23]. Mohammed Abuzalata; Ziad Alqadi, Jamil Al-Azzeh; Qazem Jaber Modified Inverse LSB Method for Highly Secure Message Hiding: International Journal of Computer Science and Mobile Computing, Vol.8 Issue.2, February- 2019, pg. 93-103.

[24]. Qazem Jaber Rashad J. Rasras, Mohammed Abuzalata, Ziad Alqadi, Jamil Al-Azzeh; Comparative Analysis of Color Image Encryption-Decryption Methods Based on Matrix Manipulation: International Journal of Computer Science and Mobile Computing, Vol.8 Issue.2, 2019/3.

[25]. Jamil Al-Azzeh, Ziad Alqadi, Mohammed Abuzalata; Performance Analysis of Artificial Neural Networks used for Color Image Recognition and Retrieving: International Journal of Computer Science and Mobile Computing, Vol.8 Issue.2, February- 2019.

[26]. Rashad J. Rasras, Mohammed Abuzalata; Ziad Alqadi; Jamil Al-Azzeh; Qazem Jaber, Comparative Analysis of Color Image Encryption-Decryption Methods Based on Matrix Manipulation International Journal of Computer Science and Mobile Computing, Vol.8 Issue.3, March- 2019, pg. 14-26.

[27]. Jamil Al-Azzeh, Bilal Zahran, Ziad Alqadi, Belal Ayyoub, Muhammed Mesleh; A Novel Based on Image Blocking Method to Encrypt-Decrypt Color; INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION VOL 3, (2019)

[28]. [28] B. Zahran, J. AL-Azzeh, Z. Al Qadi, M. Al Zoghoul and S. Khawatreh, “A MODIFIED LBP METHOD TO EXTRACT FEATURES FROM COLOR IMAGES", Journal of Theoretical and Applied Information Technology(JATIT), Vol.96. No 10, 2018.

[29]. J. AL-AZZEH, B. ZAHRAN, Z. ALQADI, B. AYYOUB, M. ABU-ZAHER, "A novel Zero-error Method to Create a Secret Tag for an Image", Journal of Theoretical and Applied Information Technology(JATIT), Vol.96. No 13, 2018.pp: 4081-4091.

[30]. J. AL-AZZEH, B. ZAHRAN, Z. ALQADI," Salt and Pepper Noise: Effects and Removal", International Journal on Informatics Visualization, Vol.2. No 4, 2018.pp: 252-256.

[31]. Jihad Nader, Ziad Alqadi, Bilal Zahran, "Analysis of Color Image Filtering Methods", International Journal of Computer Applications (IJCA), Volume 174, issue 8, 2017, pp:12-17.

[32]. Ziad Alqadi, Bilal Zahran, Jihad Nader, " Estimation and Tuning of FIR Low pass Digital Filter Parameters", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 7, Issue 2, 2017, pp:18-23.

[33]. Khaled Aldebei, Mua’ad M. Abu-Faraj, Ziad A. Alqadi, Comparative Analysis of Fingerprint Features Extraction Methods, Journal of Hunan University Natural Sciences, vol. 48, issue 12, pp. 177-182, 2022.

[34]. Dr. Mohamad Barakat Prof. Ziad Alqadi, Highly Secure Method for Secret Data Transmission, International Journal of Scientific Engineering and Science, vol. 6, issue 1, pp. 49-55, 2022.

[35]. 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.

[36]. 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.

[37]. 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.

[38]. 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.

[39]. AlQaisi Aws, Al Tarawneh Mokhled, A Alqadi Ziad, A Sharadqah Ahmad, Analysis of Color Image Features Extraction using Texture Methods, TELKOMNIKA, vol. 17, issue 3, 2018.

[40]. Ziad A AlQadi Amjad Y Hindi, O Dwairi Majed, PROCEDURES FOR SPEECH RECOGNITION USING LPC AND ANN, International Journal of Engineering Technology Research & Management, vol. 4, issue 2, pp. 48-55, 2020.

[41]. Ziad A Alqadi, Mohamad Tariq Barakat, A Case Study to Improve the Quality of Median Filter, International Journal of Computer Science and Mobile Computing, vol. 10, issue 11, pp. 19 – 28, 2021.

[42]. Dr. Hatim Ghazi Zaini Prof. Ziad Alqadi, High Salt and Pepper Noise Ratio Reduction, International Journal of Computer Science and Mobile Computing, vol. 10, issue 9, pp. 88 – 97, 2021.

[43]. Prof. Mohamad K. Abu Zalata, Hussein N. Hatamleh, Prof. Ziad A. Alqadi, Detailed Study of Low Density Salt and Pepper Noise Removal from Digital Color Images, IJCSMC, Vol. 11, Issue. 2, PP. 56 – 67, February 2022.

