International Journal of Research in Advanced Engineering and Technology
ISSN: 2455-0876; Impact Factor: RJIF 5.44
Received: 07-11-2018; Accepted: 10-12-2018
www.newengineeringjournal.in
Volume 5; Issue 1; January 2019; Page No. 23-31

Experimental investigation of method used to remove salt and pepper noise from digital color image

Ahmad Sharadqh[1], Belal Ayyoub[2], Ziad Alqadi[3], Jamil Al-azzeh[4]
[1, 3, 4] Computer Engineering Department, Al Balqa'a Applied university, Amman, Jordan
[2] Department of Mechatronics Engineering, Al Balqa'a Applied university, Amman, Jordan

Abstract
Digital color images usually corrupted with salt and pepper noise during image transmission or storing, thus it is very useful to seek an efficient method to remove this noise.
In this paper we will discuss most non-linear filters used to remove salt and pepper noise, a new method will be proposed. The introduced and the proposed filter will be tested, implemented. Comparisons between quality parameters will be done, efficiency analysis will be performed, and depending on the comparison results some judgment will be done.

Keywords: SAPN, PSNR, noise removal time, noise density, OCF, BPDF, AF, MF

1. Introduction

Digital color image [1] is usually presented by a 3D matrix, the first dimension is reserved for red color, the second for the green, and the third one is reserved for the green color, each color intensity value ranges from 0 to 255 as shown in figure [1, 2, 3, 4].

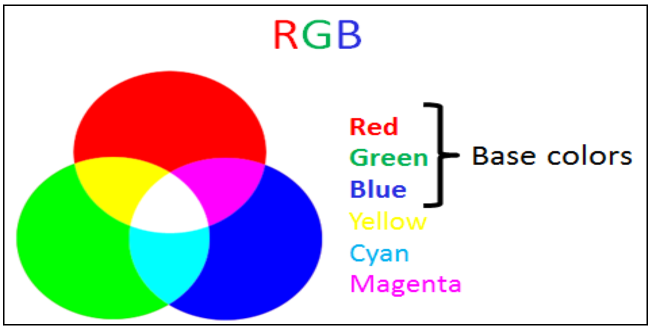


Fig 1: Color image components

The quality of digital color image deteriorates from a moment it was captured to a moment it was seen by the human eyes [5]. Digital image is subject to many kinds of distortion during any phase starting from its capturing and ending with storing phase after applying a set of preprocessing and processing operations. Impulse noise is a special type of image noises which can affect color image by various origins during image transmission, storing, Salt and pepper noise (SAPN) is one type of impulse noise which can corrupt the image, when SAPN affects the image the noisy pixels take only the maximum value 255(salt noise) and the minimum value 0 (pepper noise).
linear filtering methods and techniques are not effective in removing SAPN, so non-linear filtering methods are widely used in the process of removing SAPN, these methods give a good quality de-noised image by increasing peak signal to noise ratio (PSNR), decreasing mean square error (MSE) and increasing the correlation between the clean original image and the de-noised image [6, 7].

1.1 Median filter

The standard median filter (SMF) is one of the most popular non-linear filters used to remove SAPN due to its good de-noising power and computational efficiency [8, 9], the corrupted pixels are to be replaced by the median values as shown in figures 2 and 3.

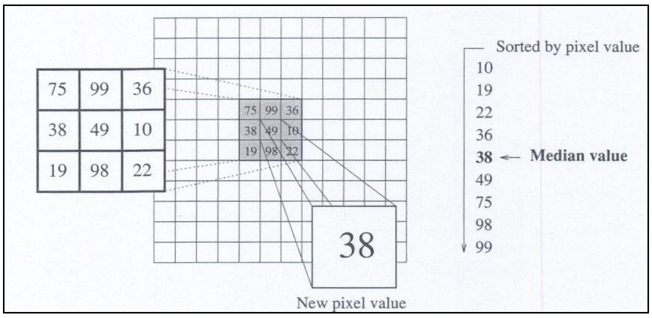
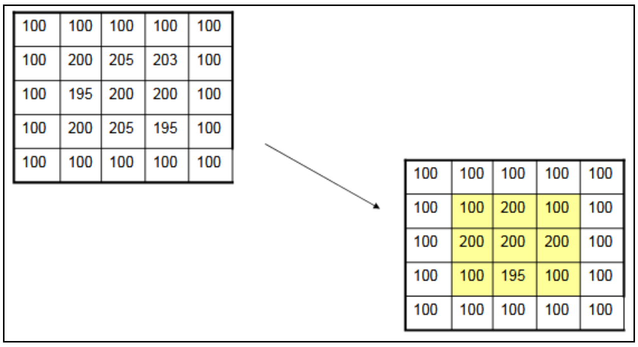


Fig 2: Operation of SMF



100	100	100	100	100
100	200	205	203	100
100	195	200	200	100
100	200	205	195	100
100	100	100	100	100

100	100	100	100	100
100	100	200	100	100
100	200	200	200	100
100	100	195	100	100
100	100	100	100	100

Fig 3: Example of using SMF

1.2 Average filter

Average filter (AF) is also a non-linear filter and it can be used to reduce the effects of SAPN, it uses a mask with variable dimension, this mask is to be convoluted with the noisy image to reduce SAPN in the corrupted image [6, 7] as shown in figures 4 and 5.

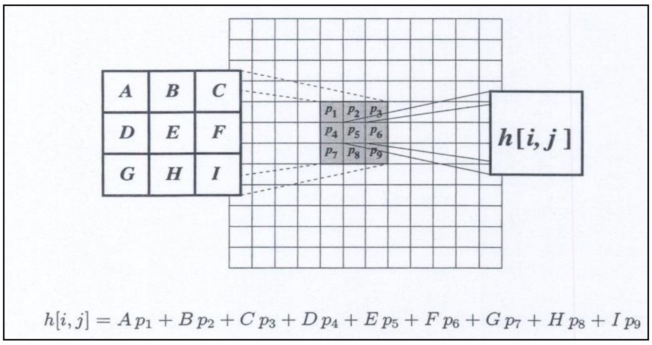


Fig 4: AF operation

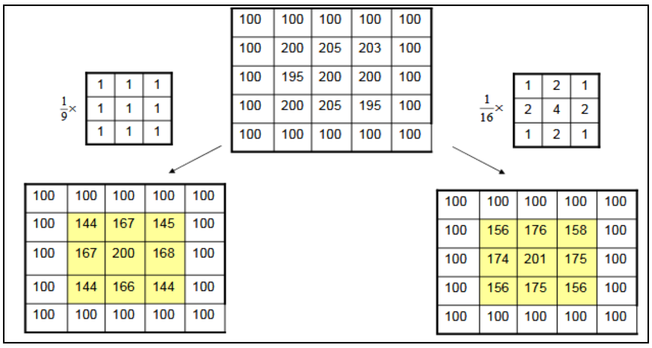


Fig 5: Example of AF

1.3 BPDF

In [10] a new method based on pixel density in salt and pepper noise removal was proposed and it was called BPDF (based on pixel density filter), this filter works in 2 stages, the first stage is to detect whether a window contains corrupted pixel, if yes replace the corrupted pixel by the average of mostly repeated values in the window, if the all the values in the window are corrupted expand the window as shown in figure 6:

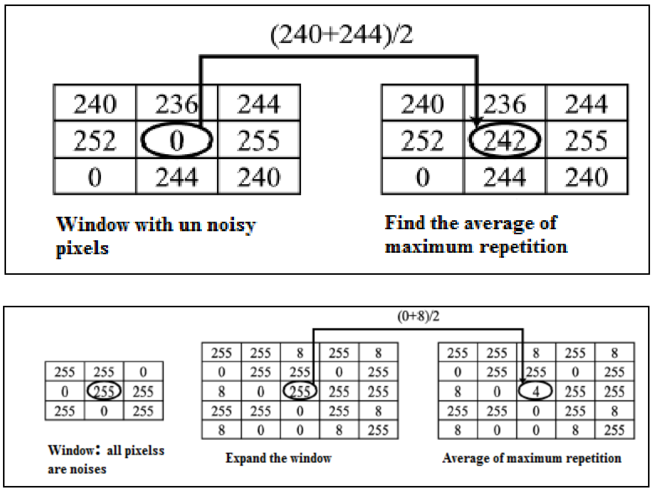


Fig 6: BPDF operation

1.4 OCF

Here we will introduce a method of SAPN removal, this method uses basic morphological operations to remove the components of SAPN (salt noise and pepper noise) [11], we will refer to this method as OCF (opening-closing filtering).
OCF can be implemented in 2 phases: the first phase is to apply opening with a 2 by 2 structuring element, opening and closing are very efficient operations to manipulate matrix processing [12, 13, 14].
Morphological opening is erosion followed by dilation using the same structuring element [11], erosion of an image removes all structures that the structuring element cannot fit inside, and shrinks all other structures, If we dilate the result of the erosion with the same structuring element, the structures that survived the erosion (were shrunken, not deleted) will be restored, applying this operation we can remove the white salt noise.
The second phase is to apply closing using the same structuring element.
Closing is image dilation followed by image erosion using the same structuring element, dilation of an object grows the object and can fill gaps, if we erode the result after dilation with the rotated structure element the objects will keep their structure and form, but small holes filled by dilation will not appear, fhus closing can be used to remove the dark points (pepper noise).

2. Filters implementation

A matlab codes were written to implement various filter, a color image was selected and affected with SAPN with deferent noise dencities(number of noisy pixels which are a percent from the total number of pixels in color image).

2.1 MF implementation

Here we can take one of the following 2 methods

1. Method 1: De-noising each color alone

This method can be implemented applying the following steps:
Removing SAPN from color image can be done applying the following steps:

A. Get the noisy color image
B. Extract the red, green, blue color matrices.
C. Select the kernel size.
D. Apply median filtering for each color matrix
E. Compose the denoised color image from the de-noised color matrices.

2. Reshaping the color image

This method can be implemented applying the following steps:

A. Get the noisy color image
B. Reshape the image to 2D matrix.
C. Select the kernel size.
D. Apply median filtering to denoise 2D matrix
E. Reshape denoised 2D matrix back to 3D matrix to get the denoisy color image.

Figure 7 shows the images treated by this filter using the first method

Fig 7: MF implementation

2.2 AF implementation

Here we can take one of the following 2 methods:

1. Method 1: De-noising each color alone

This method can be implemented applying the following steps:

Removing SAPN from color image can be done applying the following steps:

A. Get the noisy color image
B. Extract the red, green, blue color matrices.
C. Select the mask.
D. Apply convolution of each 2D matrix with the mask to get denoisy colors.
E. Compose the denoised color image from the de-noised color matrices.

2. Reshaping the color image

This method can be implemented applying the following steps:

A. Get the noisy color image
B. Reshape the image to 2D matrix.
C. Select the mask.
D. Apply convolution of the 2D matrix with the mask.
E. Reshape denoised 2D matrix back to 3D matrix to get the denoisy color image.

Figure 8 shows the images treated by this filter using the first method:

Fig 8: AF implementation

2.3 BPDF implementation

This filter can be implemented using one of the following 2 methods:

1. Method 1: De-noising each color alone

Removing SAPN from color image can be done applying the following steps:

A. Get the noisy color image
B. Extract the red, green, blue color matrices.
C. Apply BPDF for each color.
D. Compose the denoised color image from the de-noised color matrices.

2. Reshaping the color image

This method can be implemented applying the following steps:

A. Get the noisy color image
B. Reshape the image to 2D matrix.

C. Apply BPDF to denoise 2D matrix.
D. Reshape denoised 2D matrix back to 3D matrix to get the denoisy color image.

Figure 9 shows the images treated by this filter using the first method:

Fig 9: BPDF implementation

2.4 OCF implementation

This filter can be implemented using one of the following 2 methods:

1. Method 1: De-noising each color alone

Removing SAPN from color image can be done applying the following steps:

A. Get the noisy color image
B. Extract the red, green, blue color matrices.
C. Apply opening for each color.
D. Apply closing using the opened colors.
E. Compose the denoised color image from the de-noised color matrices.

2. Reshaping the color image

This method can be implemented applying the following steps:

A. Get the noisy color image
B. Reshape the image to 2D matrix.
C. Apply opening for the 2D matrix
D. Apply closing for the opened 2D matrix
E. Reshape denoised 2D matrix back to 3D matrix to get the denoisy color image.

Figure 10 shows the images treated by this filter using the first method:

Fig 10: OCF implementation

3. Experimental results and analysis

First method: Denoising each color allone:

The above mentioned filters were implemented by adding SAPN with various densities, tables 1 and 2 show the optained experimental results:

Table 1: Values for PSNR parameter (first method) Image size=384x512x3=589824

Noise density	AF	MF	BPDF	OCF
0.001	58.6018	61.6333	74.0421	91.9431
0.002	58.5292	61.6307	74.0339	91.7569
0.003	58.4039	61.6175	74.0202	91.6271
0.004	58.3270	61.5890	73.0310	91.3984
0.005	58.1472	61.5559	72.6345	91.2962
0.006	58.0345	61.5758	72.4849	90.8844
0.007	57.8824	61.5521	73.9833	91.1777
0.008	57.8087	61.5646	73.9782	90.6830

0.009	57.5609	61.5106	73.8207	90.5756
0.010	57.4431	61.5482	73.9337	90.7011
0.020	56.3592	61.2893	73.6853	89.2666
0.030	55.3359	61.2347	72.4880	88.2776
0.040	54.3787	61.0949	68.9882	85.8871
0.050	53.5877	60.6409	70.5196	84.3368
0.060	52.4453	60.5724	68.6432	82.6360
0.070	51.8717	60.4196	72.5309	81.3981
0.080	51.2269	60.1810	71.7608	79.2449
0.090	50.4852	59.8560	70.6024	77.4999
0.100	49.7219	59.6959	71.5652	75.1109
0.200	44.2029	55.4644	64.5097	56.9465
0.300	40.2051	48.3373	61.6224	44.2359
0.400	36.8650	40.6250	57.6338	36.2262
0.500	33.9975	33.1542	52.2820	30.3173

Table 2: Filtering time(seconds) (First method) Image size=384x512x3=589824

Noise density	AF	MF	BPDF	OCF
0.001	0.053000	0.061000	4.095000	0.248000
0.002	0.049000	0.059000	4.188000	0.246000
0.003	0.048000	0.059000	4.176000	0.249000
0.004	0.050000	0.059000	4.306000	0.249000
0.005	0.049000	0.059000	4.359000	0.247000
0.006	0.048000	0.059000	4.415000	0.248000
0.007	0.050000	0.060000	4.384000	0.246000
0.008	0.049000	0.062000	4.422000	0.247000
0.009	0.047000	0.065000	4.465000	0.248000
0.010	0.050000	0.060000	4.499000	0.248000
0.020	0.050000	0.077000	5.053000	0.248000
0.030	0.049000	0.060000	5.391000	0.250000
0.040	0.050000	0.061000	5.895000	0.253000
0.050	0.049000	0.062000	6.192000	0.247000
0.060	0.049000	0.061000	6.961000	0.250000
0.070	0.048000	0.060000	7.139000	0.251000
0.080	0.048000	0.062000	7.550000	0.249000
0.090	0.048000	0.061000	7.973000	0.253000
0.100	0.050000	0.061000	8.389000	0.249000
0.200	0.049000	0.062000	12.628000	0.254000
0.300	0.048000	0.062000	17.250000	0.250000
0.400	0.049000	0.063000	21.462000	0.250000
0.500	0.049000	0.061000	25.200000	0.248000

Method 2: Reshaping color image
The previous experiment was repeated but by reshaping color image to 2D image, the results of this experiment are shown in tables 3 and 4:

Table 3: Values for PSNR parameter (second method) Image size=384x512x3=589824

Noise density	AF	MF	BPDF	OCF
0.001	54.8214	56.6690	67.6192	80.0875
0.002	54.7358	56.6667	67.6055	80.0155
0.003	54.6219	56.6590	67.5760	79.8776
0.004	54.5265	56.6481	67.2977	79.7696
0.005	54.4676	56.6203	67.5609	79.7467
0.006	54.4007	56.6004	67.0213	79.6125
0.007	54.3274	56.6115	67.1885	79.5190
0.008	54.2306	56.5786	66.8064	79.3751
0.009	54.0808	56.5874	*67.5169*	79.4607
0.010	54.0434	56.5406	66.1320	79.1207
0.020	53.3057	56.4026	66.3225	78.4033
0.030	52.4476	56.3222	66.2751	77.6208
0.040	51.7955	56.1593	65.6185	76.8911
0.050	51.0102	56.0622	66.7252	75.3074
0.060	50.3592	55.8269	64.5458	74.3654
0.070	49.6827	55.7103	63.4050	73.5449
0.080	49.1440	55.4403	66.2363	72.0442
0.090	48.5079	55.3767	64.5063	70.3406
0.100	47.9813	55.1636	63.9137	68.9963

0.200	43.0134	51.9621	62.9745	55.0577
0.300	39.4225	46.7931	57.2912	43.7699
0.400	36.2224	39.3948	57.2190	35.9921
0.500	33.5749	32.7157	53.5684	30.0531

Table 2: Filtering time (seconds) (second method) Image size= 384x 512x3=589824

Noise density	AF	MF	BPDF	OCF
0.001	0.047000	0.075000	4.083000	0.242000
0.002	0.044000	0.053000	4.191000	0.228000
0.003	0.044000	0.054000	4.231000	0.230000
0.004	0.043000	0.056000	4.315000	0.229000
0.005	0.044000	0.056000	4.326000	0.228000
0.006	0.042000	0.053000	4.300000	0.233000
0.007	0.042000	0.055000	4.485000	0.228000
0.008	0.044000	0.055000	4.569000	0.230000
0.009	0.043000	0.055000	4.534000	0.230000
0.010	0.042000	0.056000	4.583000	0.230000
0.020	0.043000	0.056000	4.994000	0.229000
0.030	0.045000	0.054000	5.457000	0.233000
0.040	0.046000	0.056000	5.813000	0.232000
0.050	0.044000	0.056000	6.257000	0.233000
0.060	0.043000	0.058000	6.693000	0.230000
0.070	0.043000	0.056000	7.103000	0.236000
0.080	0.044000	0.055000	7.599000	0.233000
0.090	0.042000	0.056000	8.001000	0.236000
0.100	0.044000	0.055000	8.369000	0.233000
0.200	0.044000	0.057000	12.610000	0.231000
0.300	0.044000	0.056000	16.896000	0.231000
0.400	0.042000	0.056000	21.245000	0.232000
0.500	0.069000	0.055000	25.130000	0.231000

From the obtained experimental results shown in the previous tables we can rais the following facts

- It is beter to denoise each color allone, because the obtained results for method 1(tables 1 and 2) are better than those obtained for method 2(tables 3 and 4).
- It is beter to use OCF for SAPN removing for noise densities greater than 0.1, here we can achieve a higher value for PSNR in a small denoising time (see figure 11).
- SAPN is a sudden changes in an image due to some reasones, so the changes are small, thus the noise density usualy low, and here OCF will be the best choise to remove SAPN and it will gives an denoisy image with good quality.
- OCF requires a small amount of processing time comparing with BPDF.
- BPDF give beter results when dealing with high noise density (greater than 0.12).
- For high noise density ot is beter to use BPDF, but noise removal requires much time, this time will rapidly increases when the noise density increase (see figure 12).
- MF and AF give bad results comparing with OCF and BPDF for both low and high noise denities.

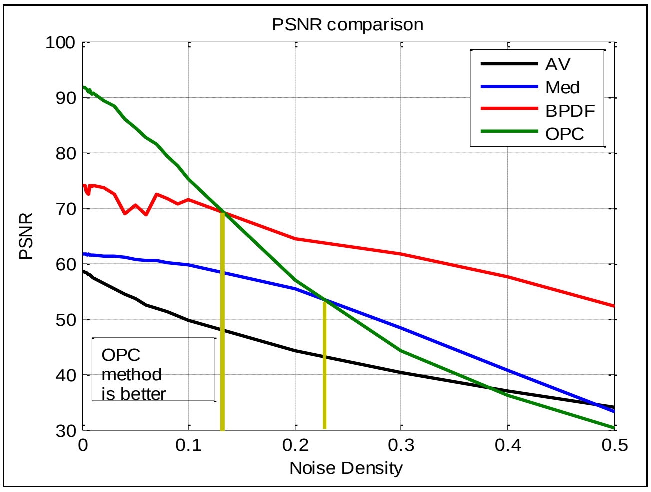


Fig 11: PSNR comparisons

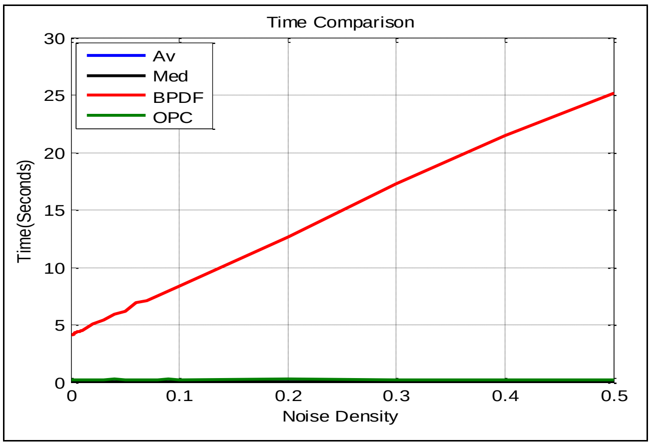


Fig 12: Noise removal time comparisons

Conclusion

Deferent methods for salt and pepper noise removel were proposed, tested and implemented.

The proposed OCF gives a beter performance and a high quality de-noised image when the noise has a low density (less than 12%), for higher dencities it is beter to use BPDF but this filter requires a big amount of time to remove salt and pepper noise.

Average and median filters give bad parameters for low and highy densities noises.

References

1. Waheeb Abu Ulbeh, Akram Moustafa, Ziad Alqadi A. Gray Image Reconstruction, European Journal of Scientific Research, ISSN 1450-216X. 2009; 27(2):167-173.

2. Majed O, Al-Dwairi, Ziad A, Alqadi Amjad A, AbuJazar, Rushdi Abu Zneit. Optimized True-color Image Processing, World Applied Sciences Journal 8 (10): 1175-1182, 2010 ISSN 1818-4952 © IDOSI Publications, 2010.
3. Alqadi, Ziad A, Moustafa, Akram A. Alduari, Majed; Zneit, Rushdi abu zneit,True Color Image Enhancement Using Morphological Operations, International Review on Computers & oftware. 2009; 4(5):557.
4. Akram Moustafa A, Ziad Alqadi A. Color Image Reconstruction Using A New R'G'I Model, Journal of Computer Science. 2009; 5(4):250-254, ISSN 1549-3636 © Science Publications.
5. Firas Ajil Jassim. Kriging Interpolation Filter to Reduce High Density Salt and Pepper Noise, World of Computer Science and Information Technology Journal (WCSIT) ISSN: 2221-0741. 2013; 3(1):8-14.
6. Jihad Nader, Ziad Alqadi A, Bilal Zahran. Analysis of Color Image Filtering Methods, International Journal of Computer Applications (0975–8887) Volume 174 – No.8.
7. Alqadi Ziad A, Moustafa Akram, Alduari Majed, Rushdi abu Zneit. True Color Image Enhancement Using Morphological Operations, International Review on Computers & Software. 2009; 4(5):557.
8. Huang TS, Yang GJ, Tang GY. Fast two-dimensional median filtering algorithm, IEEE Trans. Acoustics, Speech, Signal Process. ASSP-1. 1979; 1:13-18.
9. Chan RH, Chung-Wa Ho, Nikolova M. Pepper Noise Removal by Median Type Noise Detectors and Detail – Preserving Regularization. IEEE Transactions on Image Processing. 2005; 14(10):1479-1485.
10. Erkan U, Gokrem L. A new method based on pixel density in salt and pepper noise removal, Turk J Elec. Eng & Comp Sci. 2018; 26:162-171, doi:10.3906/elk-1705-256.
11. Ziad Alqadi A, Moustafa Akram, Alduari Majed, Rushdi abu Zneit. True Color Image Enhancement Using Morphological Operations, International Review on Computers & Software. 2009; 4(5):557.
12. Musbah J, Aqel Ziad A, Alqadi Ibraheim M. Analysis of Stream Cipher Security Algorithm, Journal of Information and Computing Science. 2007; 2(4):288-298.
13. Alqadi Z, Abu-Jazzar. Analysis of program methods used for optimizing matrix Multiplication, Journal of Engineering. 2005; 15(1):73-78.
14. Ziad Al-Qadi, Musbah Aqel. Performance Analysis of Parallel Matrix Multiplication Algorithms Used in Image Processing, World Applied Sciences Journal. 2009; 6(1):45-52.
15. Ziad Alqadi A, Majed Al-Dwairi O, Amjad Abu Jazar A, Rushdi Abu Zneit. Optimized True-RGB color Image Processing, World Applied Sciences Journal. 2010; 8(10):1175-1182, ISSN 1818-4952.
16. Moustafa AA, Alqadi ZA. Color Image Reconstruction Using A New R'G'I Model, Journal of Computer Science. 2009;5(4):250-254.
17. Matrouk K, Al-Hasanat A, Alasha'ary H, Al-Qadi Z, Al-Shalabi H. Speech fingerprint to identify isolated word person, World Applied Sciences Journal. 2014; 31(10):1767-1771.
18. Al-Azzeh J, Zahran B, Alqadi Z, Ayyoub B, Abu-Zaher M. A Novel zero-error method to create a secret tag for an image, Journal of Theoretical and Applied Information Technology. 2018; 96(13):4081-4091.
19. Ziad AA. Alqadi Mohammed K. Abu Zalata, Ghazi Qaryouti M. Comparative Analysis of Color Image Steganography, JCSMC. 2016; 5(11):37-43.
20. Jose M. Hiding Image in Image Using LSB Insertion Method with Improved Security and Quality, International Journal of Science and Research. 2014; 3(9):2281-2284.
21. Patel RM, Shah DJ. Conceal gram: Digital image in image using LSB insertion method", International Journal of Electronics and Communication Engineering & Technology. 2103; 4(1):230-2035,
22. Akhtar N, Johri P, Khan S. Enhancing the security and quality of LSB based image steganography, 5th International Conference on Computational Intelligence and Communication Networks, Mathura, India, 2013, 27-29.
23. Juneja M, Sandhu PS. An improved LSB based Steganography with enhanced Security and Embedding/Extraction, 3rd International Conference on Intelligent Computational Systems, Hong Kong China, 2013m, 26-27.
24. Alasha'ary H, Matrouk K, Al-Hasanat A, lqadi ZA, Al-Shalabi H. Improving Matrix Multiplication Using Parallel Computing, International Journal on Information Technology (I.RE.I.T.). 2013; N.6 ISSN 2281-2911.
25. 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) 2012; 85:201.
26. Alqadi ZA, Abu-Jazzar A. Analysis of Program Methods Used For Optimizing Matrix Multiplication, Journal of Engineering. 2005; 15(1):73-78.
27. Alqadi ZA, Aqel M, I.M, Emary El. Performance Analysis and Evaluation of Parallel Matrix Multiplication Algorithms, World Applied Sciences Journal. 2008; 5(2):ISSN 1818-4952.
28. Alasha'ary H, Matrouk K, Al-Hasanat A, Alqadi Z, Al-Shalabi H. Improving Matrix Multiplication Using Parallel Computing, International Journal on Information Technology (I.RE. I.T.). 2013; 1N. 6 ISSN 2281-2911.
29. Ziad Al-Qadi, Musbah Aqel. Performance analysis of parallel matrix multiplication algorithms used in image processing, World Applied Sciences Journal. 2009; 6(1):45-52.
30. Jamil Al-Azzeh, Bilal Zahran, Ziad Alqad. Salt Pepper Noise: Effects and Removal International Journal on Electrical Engineering and Informatics 2(4),
31. Vimala T. Salt and Pepper Noise Reduction Using Mdbutm Filter With Fuzzy Based Refinement. 2012; 2:5.
32. Jassim FA.Image Denoising Using Interquartile Range Filter with Local Averaging, International Journal of Soft Computing and Engineering (IJSCE). 2013; 2(6):424-428.
33. Jamil AL-Azzeh S. Distributed Mutual Inter-Unit Test Method For D-Dimensional Mesh-Connected Multiprocessors With Round-Robin Collision Resolution: Jordanian Journal of Computers and Information Technology, 2019.

34. 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.
35. Jamil AL-Azzeh, Evaluation Method for SDN Network Effectiveness in Next Generation Cellular Networks: International Journal of Communication Networks and Information Security, 2018.
36. Jamil AL-Azzeh. Improved testability method for mesh-connected VLSI multiprocessors: Jordanian Journal of Computers and Information Technology, 2018.
37. Jamil AL-Azzeh. A Novel Zero-Error Method to Create a Secret Tag for an Image; Journal of Theoretical and Applied Information Technology, 2018.
38. Jamil AL-Azzeh, Qualitative risk analysis of software development Asian Journal of Information Technology, 2018.
39. Bilal Zahran, Jamil AL-Azzeh. A Modified LBP Method To Extract Features From Color Images: Journal of Theoretical and Applied Information Technology, 2018.
40. Jamil AL-Azzeh. Information Technologies for Supporting Administrative Activities of Large Organizations; DESIDOC Journal of Library & Information Technology. 2018; 38:3.
41. Jamil AL-Azzeh A. Distributed Multiplexed Mutual Inter-Unit in-Operation Test Method for Mesh-Connected VLSI Multiprocessors; Jordan Journal of Electrical Engineering. 2017; 10:5.
42. Jamil AL-Azzeh. Fault-Tolerant Routing in Mesh-Connected Multicomputer based on Majority-Operator-Produced Transfer Direction Identifiers; Jordan Journal of Electrical Engineering. 2017; 3:2.
43. Jamil AL-Azzeh. Analysis of Self-Similar Traffic Models in Computer Networks; International Review on Modelling and Simulations, 2017, 10.
44. Jamil AL-Azzeh. Statistical Analysis of Methods Used to Enhanced Color Image Histogram; XX International Scientific and Technical Conference; Russia, 2017, 24-26.
45. Mazen Abuzaher, Jamil AL-Azzeh. JPEG Based Compression Algorithm; International Journal of Engineering and Applied Sciences. 2017; 4:4.
46. Jamil AL-Azzeh, ZigBee. Bluetooth Wi-Fi Complex Wireless Networks Performance Increasing; International Journal On Communications Antenna and Propagation. 2017; 7:1.
47. Jamil AL-Azzeh. Implementing Built-In Test in Analog and Mixed-Signal Embedded-Core-Based System-On-Chips; Asian Journal of Information Technology, Medwell Journals, 2016.
48. Jamil AL-Azzeh. Creating a Color Map to be used to Convert a Gray Image to Color Image; International Journal of Computer Applications (0975 – 8887), 2016, 153 – No2.
49. Jamil AL-Azzeh. Analysis of Second Order Differential Equation Coefficients Effects on PID Parameters International Journal on Numerical and Analytical Methods in Engineering (IRENA). 2016; 4:2.
50. Jamil AL-Azzeh. Automated Demodulation of Amplitude Modulated Multichannel Signals with Unknown Parameters Using 3D Spectrum Representation Research Journal of Applied Sciences, Engineering and Technology, Maxwell Scientific Publication, 2016.
51. Jamil S. Al-Azzeh. Adaptive Regulation of Radiated Power Radio Transmitting Devices in Modern Cellular Network Depending on Climatic Conditions. Contemporary Engineering Sciences, 2016, 9.
52. Mazin Al Hadidi, Jamil AL-Azzeh. Methods of Risk Assessment for Information Security Management, International Review on Computers and Software (I.RE.CO.S.), Vol. 11, N. 2 ISSN 1828-6003 (impact factor = 6.14), 2016.
53. Jamil AL-Azzeh. Bidirectional Virtual Bit-slice Synchronizer: A Scalable Solution for Hardware-level Barrier Synchronization. Research Journal of Applied Sciences, Engineering and Technology. 2016; 11(8):90-909**.** Maxwell Scientific Publication Corp.
54. Jamil AL-Azzeh. The Organization of Built-in Hardware-Level Mutual Self-Test in Mesh-Connected VLSI Multiprocessors; International Journal on Information Technology (I.RE.I.T.) Vol. 3, Praise Worthy Prize, 2015.
55. Jamil AL-Azzeh. An approach to achieving increased fault-tolerance and availability of multiprocessor-based computer systems; Australian Journal of Basic and Applied Sciences, 2014.
56. Jamil AL-Azzeh, Computer simulation of vibration robot created for the wall movement; Research Journal of Applied Sciences. 2014; 9:597-602.
57. Jamil AL-Azzeh. Review of Methods of Distributed Barrier Synchronization of Parallel Processes in Matrix VLSI Systems, International Review on Computers and Software (IRECOS), Praise Worthy Prize, Part A. 2013; 8(4):42-46.
58. Jamil AL-Azzeh. Fastest Color Model for Image Processing Using Embedded Systems Australian Journal Of Basic And Applied Sciences. 2013;7(14):83-89.
59. Jamil AL-Azzeh. Using Virtual Network to Solve Freight Company Problems; World Applied Sciences Journal 27 (6): 754-758, ; (SJR indicator = 0.17)
60. Jamil AL-Azzeh, Detection of eyes using FCM, International Review on Computers and Software (IRECOS), Praise Worthy Prize, Part A. 2012; 7(4) pp.1428-1434, Jul. (impact factor = 6.14).
61. Jamil AL-Azzeh, An optical character recognition, Contemporary Engineering Sciences, vol. 5, no. 11, pp. 521-529, 2012.
62. Jamil AL-Azzeh, Analysis of Matrix Multiplication Computational Methods European Journal of Scientific Research. 2014; 121(3):258-266.
63. Ziad A, Al-Qadi, Musbah J. Aqel Performance analysis of parallel matrix multiplication algorithms used in image processing: World Applied Sciences Journal. 2009; 6(1):45-52.
64. 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. 2019; 8(2):93-103.
65. Qazem Jaber, Rashad Rasras J, 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. 2019; 8(2):3.

66. 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. 2019; 8:2.
67. Rashad Rasras J, 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. 2019; 8(3):14-26.
68. 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. 2019; 3:1.
69. Jamil Al-Azzeh, Zahran B, Alqadi Z, Ayyoub B, Mesleh M. A Novel Based On Image Blocking Method To Encrypt-Decrypt Color, International Journal on Informatics Visualization. 2019; 3:1.
70. Zahran B, AL-Azzeh J, Al Qadi Z, Al Zoghoul M, Khawatreh S. A Modified LBP Method to Extract Features from Color Images, Journal of Theoretical and Applied Information Technology(JATIT). 2018; 96:10.
71. AL-Azzeh J, Zahran B, Alqadi Z, Ayyoub B, Abu-Zaher M. A novel Zero-error Method to Create a Secret Tag for an Image, Journal of Theoretical and Applied Information Technology(JATIT). 2018; 96(13):4081-4091.
72. Jamil AL-Azzeh, Zahran B, Alqadi Z. Salt and Pepper Noise: Effects and Removal, International Journal on Informatics Visualization. 2018; 2(4):252-256.
73. Jihad Nader, Ziad Alqadi, Bilal Zahran. Analysis of Color Image Filtering Methods, International Journal of Computer Applications (IJCA). 2017; 174(8):12-17.
74. 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. 2017; 7(2):18-23.