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Comparative Analysis of Methods Used to Remove Salt and Pepper Noise

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Abstract: In this paper, we will introduce a new method capable to remove or reduce salt and pepper noise (OPCLOSE method). The first phase of the method is to remove salt noise points by applying morphological image opening, while the next phase will remove the pepper noise points by applying morphological image closing. A comparative experimental analysis will be performed for various method of salt and pepper noise removal.

The existing methods of salt and pepper noise removal such as based on pixel density filter method (BPDF), average filtering, median filtering, and other method.

Salt and pepper noise removal method will be tested using noisy gray and color images, PSNR and MSE will be calculated in order to do some recommendation based on the on the calculated quality factors

Keywords: Salt and pepper noise, noise removal, opening, closing, PSNR, MSE, correlation coefficient.

1. Introduction

1- Introduction

Digital gray image [1] is a 2D matrix with values range from 0 to 255, while the color image is a 3D matrix to represent the red, green and blue colors as shown in figure 1[2], [3], [4].

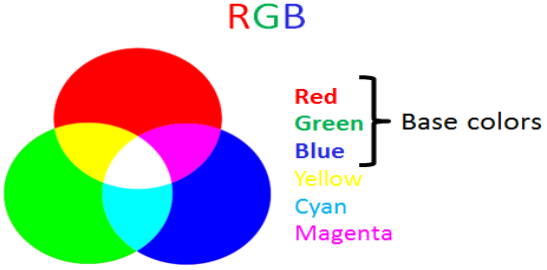

Figure 1: Color image components

The quality of gray image or 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 of the image processing, the distortion may be occur as a result of affecting the image by a noise such as salt and pepper noise which can affect gray image or affect one or more components of the color image [5], [6]. Salt and Pepper noise is generally caused by a defected of camera sensor, software, or hardware failure in image capturing or transmission. Due to this situation, Salt & Pepper noise model, only a proportion of all the image pixel s are corrupted whereas other pixels are non-noisy [7], [12]. A standard Salt & Pepper noise value may be either minimum (0) or maximum (255). The typical intensity value for pepper noise is close to 0 and for salt noise is close to 255. Furthermore, the unaffected pixels remain unchanged. Figures 1 shows an example of gray and color images affected by salt and pepper noise.

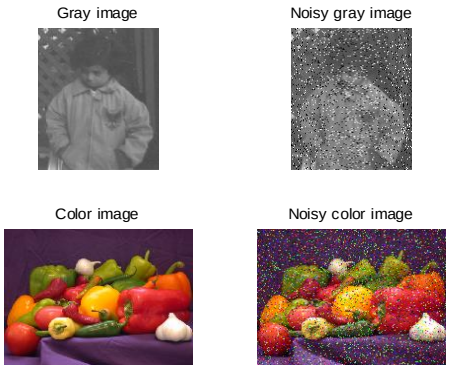

Figure 2: Example of affected images

Many methods and techniques are now widely used to remove or reduce salt and pepper noise and here we will introduce some of them.

1-1 Median filter

Median filter is a nonlinear filter widely used to remove salt and pepper noise [8], [9], it uses a kernel usually 3 by 3 and it treat the noise by manipulating each pixel by sorting the values of the neighbors covered by the kernel and setting the pixel value to a new one which is located in the middle of the sorted neighbors values (median) as shown in figure 3.

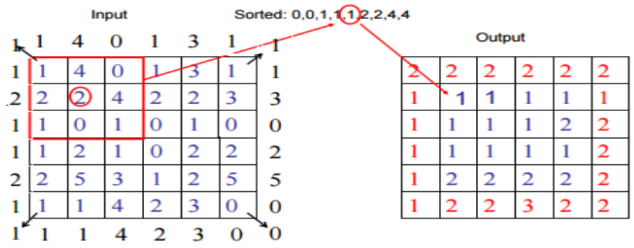

Figure 3: Median filtering

1-2 Average filter

The average filter uses a mask and noise reduction can be done by applying convolution between the mask and the noisy image [11] as shown in figure 4:

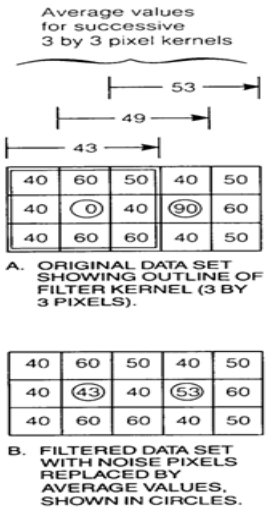

Figure 4: Average filtering

1-3 Gaussian filter

Gaussian filter is used to smooth the image by applying convolution between the noisy image and a mask giving by formula (1):

$$h_g(n_1, n_2) = e^{-(n_1^2 + n_2^2)/(2\sigma^2)}$$

$$h(n_1, n_2) = \frac{h_g(n_1, n_2)}{\sum_{n_1}\sum_{n_2} h_g} \qquad \textbf{(1)}$$

Where sigma is a positive standard deviation and n1 and n2 are the mask dimensions [12], [15].

1-4 Laplacian filter

This filter used a mask calculated by using the gradient of the second order partial derivative as shown in formula (2), applying convolution of this mask with the noisy image we can smooth the noisy image

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

$$\nabla^2 \approx \frac{4}{(\alpha+1)} \begin{bmatrix} \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \\ \frac{1-\alpha}{4} & -1 & \frac{1-\alpha}{4} \\ \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \end{bmatrix} \qquad \textbf{(2)}$$

The parameter alpha is used to control the shape of the Laplacian filter and must be in the range 0.0 to 1.0 [13], [15].

1-5 LoG (Laplacian of Gaussian) filter

Log is a rotationally symmetric Laplacian of Gaussian filter and it uses a mask calculated by formula (3) to smooth the noisy image:

$$h_g(n_1, n_2) = e^{-(n_1^2 + n_2^2)/(2\sigma^2)}$$

$$h(n_1, n_2) = \frac{(n_1^2 + n_2^2 - 2\sigma^2) h_g(n_1, n_2)}{2\pi\sigma^6 \sum_{n_1}\sum_{n_2} h_g} \qquad \textbf{(3)}$$

1-6 BPDF method

A based on pixel density filter (BPDF) was proposed in [16], this filter can be implemented in 2 phases. The first phase of the BPDF is to determine whether or not a pixel is noisy, and the second phase to decide on an adaptive window size that accepts the noisy pixel as the center.

1-7 Quality parameters

Here in this paper we will use mean square error (MSE) and peak signal to noise ratio (PSNR) [6], [15] to measure the quality after removing salt and pepper noise, this can be done using original un noisy image and denoised image.

MSE can be calvulated using formula (4), while formula (5) used to calculate PSNR:

$$MSE := \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} (e(i,j) - f(i,j))^2 \qquad \textbf{(4)}$$

$$PSNR := 10 \log \left(\frac{255^2}{MSE} \right) \qquad \textbf{(5)}$$

The higher the PSNR value is the higher quality of noise removal; while the lower the MSE value is the higher of the noise removal.

2. Experimental Results of Existing Methods

A gray image was affected by salt and pepper noise with using various noise densities (number of affected pixels in the image), table (1) shows the implemntation results by applying average filtering

Table (1) : Results for average filter
Image size=291x240=69840 pixels, Mask 3 by 3

Noise density	Number of affected pixels	PSNR	MSE	CC(correlation coefficient)
0.0010	70	32.9326	25.5409	0.9765
0.0020	140	32.6001	27.5730	0.9746
0.0040	280	31.9746	31.8447	0.9706
0.0100	699	30.6663	43.0395	0.9604
0.0200	1397	29.2559	59.5537	0.9456
0.0300	2096	28.1029	77.6619	0.9298
0.0400	2793	26.9324	102.5938	0.9081
0.0500	3492	26.2459	120.1628	0.8932
0.0600	4190	25.6029	138.1036	0.8789
0.0800	5587	24.4540	179.9271	0.8452

Table (2) shows the results for median filter, while table (3) shows the results for BPDF method:

Table (2): Results for median filter
Image size=291x240=69840 pixels, Mask 3 by 3

Noise density	Number of affected pixels	PSNR	MSE	CC
0.0010	70	40.5138	4.4577	0.9959
0.0020	140	40.5003	4.4717	0.9959
0.0040	280	40.4899	4.4824	0.9959
0.0100	699	40.3362	4.6439	0.9957
0.0200	1397	39.4583	5.6841	0.9947
0.0300	2096	39.5300	5.5911	0.9948
0.0400	2793	39.9367	5.0913	0.9953
0.0500	3492	38.9153	6.4411	0.9940
0.0600	4190	38.6546	6.8397	0.9936
0.0800	5587	38.8967	8.3832	0.9922

Table (3): BPDF method results

Noise density	Number of affected pixels	PSNR	MSE	CC
0.0010	70	68.6065	0.0069	1.0000
0.0020	140	64.1170	0.0194	1.0000
0.0040	280	59.1143	0.0615	0.9999
0.0100	699	55.6351	0.1371	0.9999
0.0200	1397	52.8085	0.2628	0.9998
0.0300	2096	51.3263	0.3697	0.9997
0.0400	2793	49.3804	0.5787	0.9995
0.0500	3492	47.9906	0.7970	0.9993
0.0600	4190	46.9768	1.0065	0.9991
0.0800	5587	45.3251	1.4723	0.9986

The other methods were excluded from the analysis because of bad obtained experimental results as shown in table (4):

Table (4): Other methods results

Method	Number of affected pixels	PSNR	MSE	CC
Gaussian mask 3 by 3 and sigma=0.5	70	20.0377	575.7940	0.6621
Laplacian alpha =0.2	70	7.6791	11096	-0.0597
LoG mask 3 by 3 and sigma=0.5	70	7.8091	10769	-0.0661
Prewitt	70	7.4713	11640	0.1064
Sobbel	70	7.5799	11353	0.1197
Un sharp with alpha=0.2	70	24.5655	227.2637	0.8520

3. The Proposed Method

The proposed here OPCLOSED method can be implemented applying the fo;;owing steps:

- Select a structuring element with size 2 by 2[17].
- Apply morphological opening operation to remove the salt noise.
- Apply morphological closing operation to remove the pepper noise.

This method was implemented using the same image, figures (5) and (6) show the results of noise removing using defernt noise dencities.

The same image with size =291x240=69840 pixels was affected by salt and pepper noise with various values of noise density, the proposed method was implemented using 3 b 3 and 2 by 2 structuring elements and as shown in tables (5) and (6) we can recommend using a 2 by 2 structuring element to increase the quality of the proposed method.

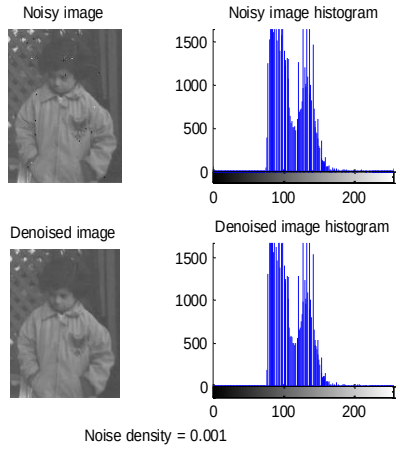

Figure (5): Example 1 of using OPCLOSE method

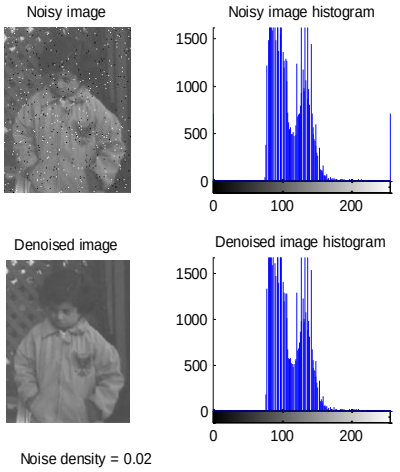

Figure (6): Example 2 of using OPCLOSE method

Table (5): Results using structuring element 3 by 3

Noise density	Number of affected pixels	PSNR	MSE	CC
0.0010	70	37.4680	8.9888	0.9919
0.0020	140	37.6339	8.6519	0.9922
0.0040	280	37.4273	9.0733	0.9919
0.0100	699	37.1333	9.7088	0.9913
0.0200	1397	37.0971	9.7901	0.9913
0.0300	2096	36.4764	11.2942	0.9901
0.0400	2793	34.6994	17.0041	0.9849
0.0500	3492	32.8769	25.8705	0.9769
0.0600	4190	32.3012	29.5380	0.9736
0.0800	5587	30.1977	47.9436	0.9578

Table (6): Results using structuring element 2 by 2

Noise density	Number of affected pixels	PSNR	MSE	CC
0.0010	70	43.2184	2.3914	0.9978
0.0020	140	43.1142	2.4495	0.9977
0.0040	280	43.1386	2.4358	0.9978
0.0100	699	42.6127	2.7493	0.9975
0.0200	1397	40.6722	4.2981	0.9961
0.0300	2096	41.8296	3.2926	0.9970
0.0400	2793	40.9836	4.0007	0.9964
0.0500	3492	39.7520	6.8846	0.9937
0.0600	4190	39.1962	6.0377	0.9945
0.0800	5587	35.0624	20.2695	0.9815

Figure (7) shows a comparison between the proposed method and BPDF and median filter methods:

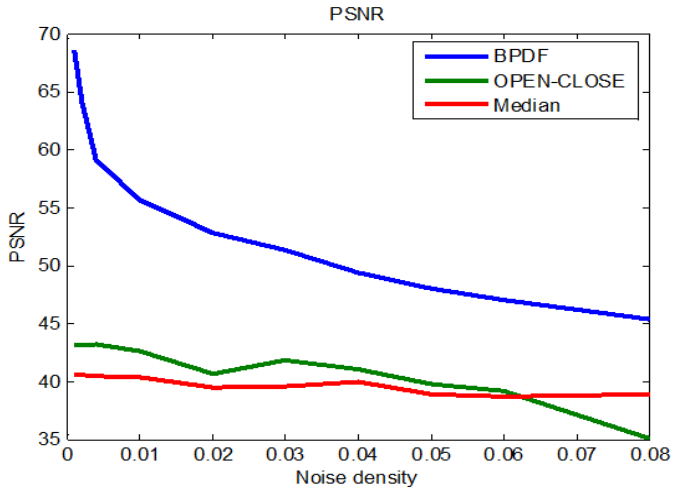

Figure (7): Results comparison

From figure (7) we can see that BPDF method gave the best results for salt and pepper noise removal, and the proposed method has a medium capability which falls between BPDF and median filter method.

1- Using OPENCLOSE method to remove salt and pepper noise from color image

The proposed OPENCLOSE method was applied using affected with salt and pepper noise color image, the noisy red, green and blue components were treated using OPCLOSE method to remove the noise, then after that the de-noised colors were used to form the de-noised color image, figure (8) shows an example of color image de-noising:

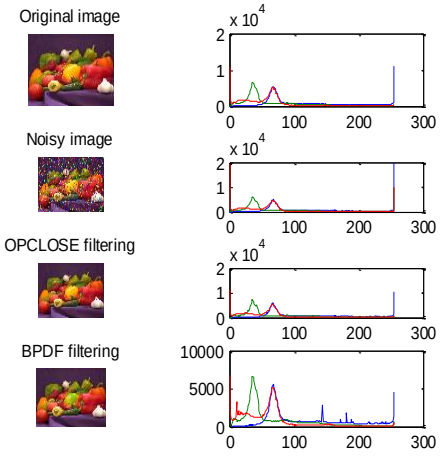

Figure (8): Example of de-noising color image

The affected color image was treated by OPCLOSE and BPDF method using various values of noise density, table (7) shows the obtained experimental results:

Table (7): Color image de-noising results

Noise density	OPCLOSE method		BPDF method	
	PSNR	MSE	PSNR	MSE
0.01	90.5823	7.5708	73.9403	39.9846
0.02	89.5420	8.4008	72.5013	46.1731
0.03	87.7201	10.0796	72.0687	48.2144
0.04	86.8240	11.0245	72.6531	45.4773
0.05	84.6622	13.6851	72.6964	45.2809
0.06	82.8355	16.4278	70.3482	57.2661
0.07	81.1423	19.4587	71.7191	49.9297
0.08	79.7474	22.3715	69.3453	63.3071
0.09	77.0974	29.1598	66.6366	83.0019
0.10	74.3666	38.3159	60.3683	155.3532

From table (7) we can see that the quality parameters of OPENCLOSE method are better than those for BPDF method (see figure 9), and here we can recommend OPENCLOSE method for salt and pepper noise removal in color images.

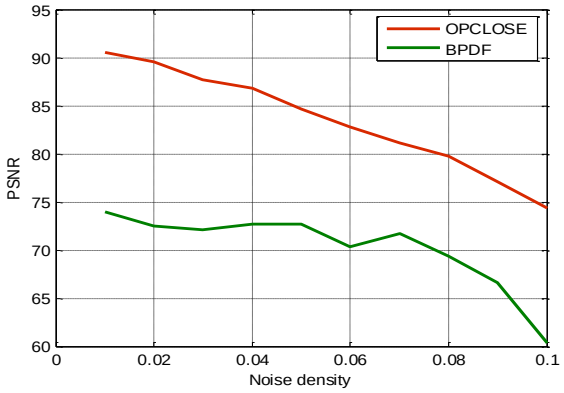

Figure (9): OPENCLOSE and BPDF comparisons

4. Conclusion

The proposed OPENCLOSE method was tested and implemented, a comparative experimental analysis was done, the obtained experimental results showed the following facts:

- The best method for salt and pepper noise removal in gray image is BPDF.
- The quality of noise reduction for OPENCLOSE method using gray image it better than median filter but lower than BPDF quality.
- For removing salt and pepper noise from color image, the best method to use is OPENCLOSE method because it gave the highest PSNR values and the lowest MSE values.

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