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Window Median Filter (WMF) to Eliminate Salt and Pepper Noise from Digital Color Image

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Abstract

A color digital image is a very important type of digital data, and this image may be exposed to the effect of negative noise, which distorts it and changes some of its characteristics. Therefore, it is necessary to search for a way to get rid of this noise. In this research paper, we an easy and flexible way to deal with salt and pepper noise will be presented tested and implemented, this method will base on selecting a window to deal with the noisy pixels based on median filter, image padding will be used to select the window with a suitable size. The practical results of the proposed method will be matched and compared with other methods used to remove noise to prove the efficiency of the proposed method for removing noise from the digital color image.

Keywords: SAPN, NR, image padding, window, AVF, MF, WMF, PSNR, MSE.

Introduction

The digital color image [22-26] is an important type of data used in important vital applications due to its easy access, negligible cost, and ease of processing [7], [8]. The colored digital image, as shown in the figure 1, is represented by a three-dimensional matrix, where the first dimension is assigned to the red color, the second dimension to the green color, and the third dimension to the blue color, and each color of the colored pixel has a value ranging from 0 to 255 [9] [10].

Figure 1: Color image representation

The digital color image is sometimes subjected to the effect of noise, which leads to changing the features of the image and altering the data included in the composition of the image, which negatively affects its properties.

One of the types of noise that negatively affect the colored image is salt and pepper noise (SAPN)[19], [21], this noise changes the values of some pixels in the image to values 0 or 255. The negative impact of this noise increases with the increase in the number of pixels that have changed or by increasing the noise ratio (NR), which is measured by the number of affected pixels to the total number of pixels in the image. The SAPN noise of the digital color image leads to an increase in the number of repetitions of each of the zero and 255 in each of the three colors, and this can be seen in the image color histograms as shown in figures 2 and 3[12-16].

Figure 2: Clean color image example

Figure 3: Noisy color image

The noise in the digital color image is processed by processing the matrix of each color separately [17-20], and after processing the noise in each color [14], the colors are recombined in one matrix to form the filtered color image, as shown in the figure 4.

Figure 4: Color image filtering

The proposed method for eliminating SAPN is based on generating a window used to calculate the pixel value in the matrix in which noise is to be processed. The maximum window size will depend on the padding factor used to expand the image size (rows and column), figure 5 illustrates an example of matrix padding:

Figure 5: Example of matrix padding

Related works

Multiple methods are used to get rid of the negative effects of SAPN or mitigate them as much as possible, and many of these methods depend on average and median filters. Each pixel in the noise-affected image is processed depending on the median value as shown in the figure 6 and on the average values as shown in the figure 7.

Figure 6: Median filter

Figure 7: Average filter

The quality of the filtered image can be calculated using mean square error (MSE) or peak signal to noise ratio (PSNR), the lower the value of MSE is, the better the quality of the de-noised image, while the higher the value of PSNR is, the better the quality of the de-noised image [19], [20], [27]. MSE and PSNR can be calculated using equations 1 and 2 [15-17]:

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \|f(i,j) - g(i,j)\|^2 \quad (1)$$

$$PSNR = 20 \log_{10} \left(\frac{MAX_f}{\sqrt{MSE}} \right) \quad (2)$$

Median and average filters are effective when the noise ratio (NR) has a small value, and they fail to get a good quality filtered image when NR has a high value.

To demonstrate the effectiveness of the proposed WMF will be compared with the standard median and average filters, it will be also compared with other six popular methods based on median filter used to eliminate salt and pepper noise. These methods are: Two_ stage filter (TSF) [1], switching median (SM) filter [2], the directional weighted median (DWM) filter [3], the modified directional weighted median (MDWM) filter [4], the modified directional weighted (MDW) filter [5] and the three-values-weighted (TVW) filter [6], among these filters the most effective filters are TVW TSF filters, these filters gave good value for PSNR when NR has a small value, but increasing NR will rapidly decrease the value of PSNR making then inefficient.

The proposed WMF

The proposed window median filter uses a window with a suitable size to process each pixel in the noisy image, the maximum size of this window is depend on the padding factor used to expand the noisy image size. WMF uses the following matrices to process the noisy image:

- 3 noisy matrices A, one for each color.
- Zero_one B for each color, 0 in B means that the associated pixel in A is noisy pixel.
- Padded matrix PA for each color, this matrix is to be used to create a window for each pixel in A.
- Zero_one PB matrix for each color.

Figures 8-10 illustrate an example of these matrices:

232	163	68
170	89	79
132	59	55

Image

232	0	68
170	255	79
132	59	55

Noisy image: A

1	0	1
1	0	1
1	1	1

ZOI: B

0: noisy pixel
1: clean pixel, not to be changed

Figure 8: Matrices A and B

255	79	79	255	170	170	255	79	79	255	170	170	255
59	55	55	59	132	132	59	55	55	59	132	132	59
59	55	55	59	132	132	59	55	55	59	132	132	59
255	79	79	255	170	170	255	79	79	255	170	170	255
0	68	68	0	232	232	0	68	68	0	232	232	0
0	68	68	0	232	232	0	68	68	0	232	232	0
255	79	79	255	170	170	255	79	79	255	170	170	255
59	55	55	59	132	132	59	55	55	59	132	132	59
59	55	55	59	132	132	59	55	55	59	132	132	59
255	79	79	255	170	170	255	79	79	255	170	170	255
0	68	68	0	232	232	0	68	68	0	232	232	0
0	68	68	0	232	232	0	68	68	0	232	232	0
255	79	79	255	170	170	255	79	79	255	170	170	255

Required pixel 232, Created window

Padded image: PA

Figure 9: Matrix PA

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

ZOPI:PB

Window

Figure 10: Matrix PB

Using the above mentioned matrices WMF method can be implemented applying the following sequence of steps:

- For each color in the noisy image get the A matrix.
- Create B matrix using A.
- Calculate PA and PB matrices based on the padding factor.
- 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.
- Create a window for the pixel.
- 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.
- Recombine the matrices A to get the filtered color image.

Implementation and experimental results

The proposed method was implemented using matlab and using various images affected with SAPN with various values of NR, figures 11 shows sample outputs of the implementations, the same image with the selected NRs were treated using median and average filters, figure 12 and 13 show sample outputs of the implementations. From figures 11-13 we can see that median and average filters fail to deal with SAPN when the NR has a big value, while using the proposed method gives good results making the de-noised image clear.

Several images with various size and with NR=30 % and 1% were processed using average, median and the proposed method. Tables 1 and 2 show the obtained experimental results, and from these tables we can see that the proposed method is more effective comparing with average and median filters by increasing the value of the quality parameter PSNR using low and high value of NR (here we have to notice that different windows with various sizes were tested and the best result were obtained when using 15 by 15 window).

Figure 11: Image de-noising using WMF

Figure 12: Image de-noising using MF

Figure 13: Image de-noising using WAVF

Table 1: Results of PSNR when using NR=30%

Image number	Size(byte)	PSNR		
		AVF	MF	WMF
1	150849	34.3773	39.4197	44.5085
2	77976	33.6825	39.8741	49.0442
3	518400	39.0262	49.5244	46.0746
4	5140800	40.8157	52.2515	63.5392
5	4326210	40.8616	51.9803	62.6835

6	122265	40.4672	46.7214	58.5262
7	518400	38.1444	49.2502	35.7602
8	150975	39.2146	50.5457	71.1516
9	150975	40.1529	48.6243	59.7539
10	151353	35.9369	41.7899	47.9748
11	1890000	39.0391	51.6763	51.8259
12	6119256	44.5727	55.8689	78.4534

Table 2: Results of PSNR when using NR=1%

Image number	Size(byte)	PSNR		
		AVF	MF	WMF
1	150849	45.3914	47.7595	56.8420
2	77976	46.3191	49.8979	62.8599
3	518400	60.6741	65.6901	63.1732
4	5140800	65.0463	70.3947	86.5702
5	4326210	65.1500	70.6814	86.9553
6	122265	54.5342	56.2787	76.5895
7	518400	59.2544	64.0380	59.3154
8	150975	63.5210	76.2082	89.6229
9	150975	57.5238	61.5254	79.8003
10	151353	48.0032	49.6497	62.6202
11	1890000	64.8693	78.6412	59.2040
12	6119256	72.8933	85.1952	100.5824

A noisy big size image with various values of NR was treated using AVF, MF and WMF filters, table 3 shows the obtained experimental results:

Table 3: Processing big size image with various NR

	Image size =6119256 bytes		
Noise ratio %	AVF	MF	WMF
0.1	78.1895	85.4145	103.4917
0.5	75.4669	85.3287	102.1194
1	72.8490	85.1865	100.5857
5	62.2846	83.9810	93.0582
10	56.0286	81.3206	87.8709
20	49.0580	69.8706	82.1169
30	44.5997	55.9318	78.3542
40	41.2334	44.6085	75.6811
50	38.5301	35.8118	73.4704
60	36.2733	28.9764	71.6720
70	34.2660	23.5115	70.0586
80	32.4569	19.1260	68.4720
90	30.8931	15.6763	66.5589

From table 3 we can see that the proposed WMF filter gave good results of PSNR values for small and big value of, and the proposed method is more efficient than AVF and MF filters as shown in figure 14.

The same procedures were repeated using smaller noisy image and applying various values of NR, table 4 shows the obtained experimental results, and here the proposed method is more efficient than AVF and MF filters, by increasing the value of PSNR raising the quality of the de-noised image, this is shown in figure 15.

Figure 14: Methods comparisons when using big noisy image

Table 4: Processing small size image with various NR

	Image size =122265 bytes		
Noise ratio %	AVF	MF	WMF
0.1	54.5638	56.3097	76.4093
0.5	51.4473	55.8188	71.2804
1	48.6044	55.0023	67.1494
5	51.6411	55.8250	61.6211
10	48.6297	55.0343	66.9231
20	44.2448	52.1974	61.8917
30	40.6677	47.0517	58.5704
40	37.5956	39.9259	55.8379
50	35.3553	33.4367	53.8008
60	33.0990	27.3216	52.1707
70	31.1181	22.3388	50.7220
80	29.3245	18.1623	49.2371
90	27.6969	14.9061	47.6823

Figure 15: Methods comparisons when using smaller noisy image

TVW and TSF are the most efficient methods of treating SAPN among the filters mentioned in the related work section, the proposed method was compared with these method using noisy lena.jpg color image with various values of NR, figure 16 shows some samples of implementing the proposed method, while table 6 shows a comparisons of the obtained results:

Figure 16: Treating noisy lena.jpg image using the proposed method

From table 5 we can see that the proposed WMF filter is more efficient than both TVW and TSF filter by keeping the quality of the de-noised color image higher increasing the value of PSNR for any value of NR, this can be seen in figure 17.

Table 5: Comparisons with other famous methods

NR %	PSNR		
	TVW	TSF	WMF
10	42.53	43.08	75.2566
20	39.12	39.87	70.0125
30	36.92	37.63	66.5354
40	35.16	35.79	63.9424
50	33.87	34.02	61.7377
60	32.29	32.13	59.7208
70	30.95	31.10	57.7938
80	29.12	29.45	56.0561
90	26.84	27.16	53.2034

Figure 17: Comparisons between TVW, TSF and WMF filters

Conclusion

A new method of eliminating SAPN was proposed and implemented; this method is flexible and easy to use. The proposed method gave a high quality and clear de-noised image using various values of NR (small and big values); the obtained experimental results were compared with AVF and MF and the results of comparisons showed that the proposed method is more efficient when dealing with small or big noisy images with any value of NR, keeping in mind that AVF and MF filters some times fail to get a clear de-noised image (when the value of NR is high). The proposed method was also compared with some famous filters, and the results of comparisons also shows the advantages of the proposed method of getting de-noised image with high quality even if the value of NR is high.

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Interests: Image Processing, Algorithms, Combinational Optimization, Computer Applications and Programming.