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High Salt and Pepper Noise Ratio Reduction

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Abstract
Colored digital images are affected by salt and pepper noise, affecting their clarity, contents and properties. The negative effect on the image increases with the increase in the noise level. Filters based on average and median filters are not able to remove SAPN with high noise ratios, and accordingly, blurred images are obtained that cannot be dealt with in various image processing operations. In this paper research a modification will be add to median and average filters making them capable of reducing the noise even it has a high noise ratio, the modified average and median filters will be implanted and some comparisons with other popular filters will be made to show the enhancement of the modified filters.

Keywords: SAPN, NR, MSE, PSNR, MAVF, MMF, PF, ZOA, ZOPA.

Introduction
The colored digital image is one of the most widely used types of digital data [24-27], as it is used in many vital and important operations in practical life [15], [16], such as protection systems that analyze fingerprints or face, medical systems, and systems for protecting secret messages using the process of hiding confidential data in image [22], [23] and many other systems. Various applications require that the digital image be clear and that its contents and characteristics are preserved without any change [19], [21], but for various reasons the digital image may be affected by noise such as salt and pepper noise (SAPN) [12], [13]. SAPN negatively affects the color digital image, which makes it unclear or affects its contents and characteristics, which negatively affects the results of the application that uses this image. The extent of the negative impact of SAPN depends on the degree of noise (noise ratio: NR) and the size of the digital image (see figure 3)[20]. If the noise ratio is very high (more than 40%), the digital image becomes completely distorted and difficult to distinguish with the naked eye, which requires reprocessing the digital image to get rid of the noise [11], [14]. SAPN in a digital image changes the values of some pixels (the number of changed pixels depends on NR) to zero or 255, this will be reflected and clearly seen in the image histogram as shown in figures 1 and 2, the repetition of zeros and 255s value will be increased, and it will be rapidly increase when the noise ratio has a high value[15], [17].

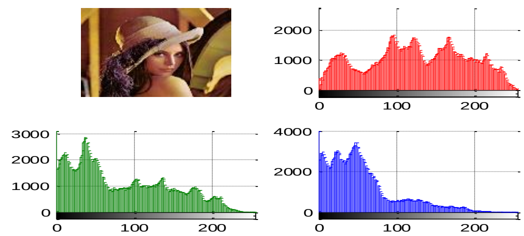

Figure 1: Clear color image example

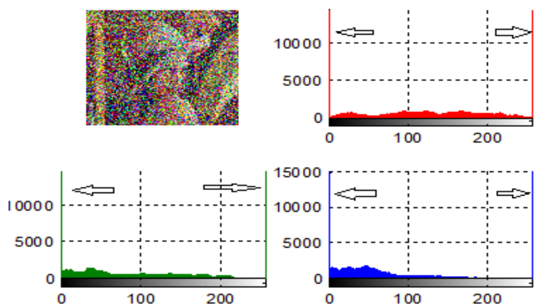

Figure 2: Noisy image

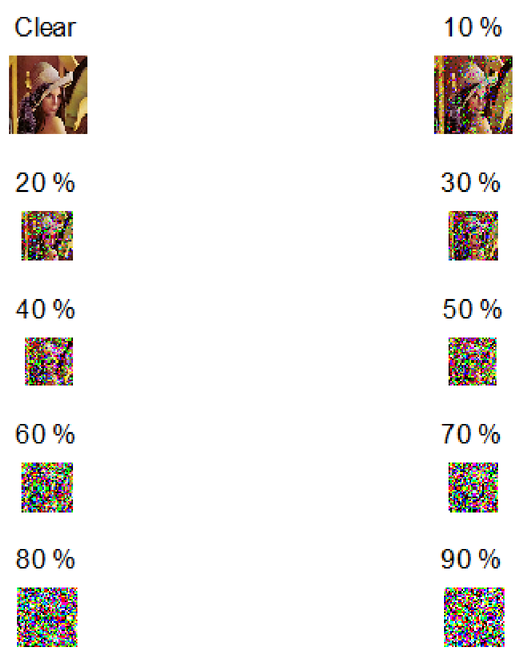

Figure 3: Effects of various NR values

Related works

Many methods used to deal with SAPN negative effects are based on median and mean filters, these filters act as shown in figures 4 and 5.

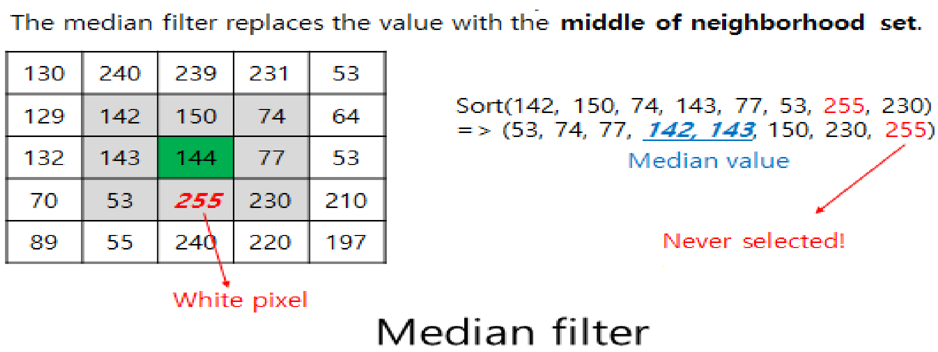

Figure 4: Median filter

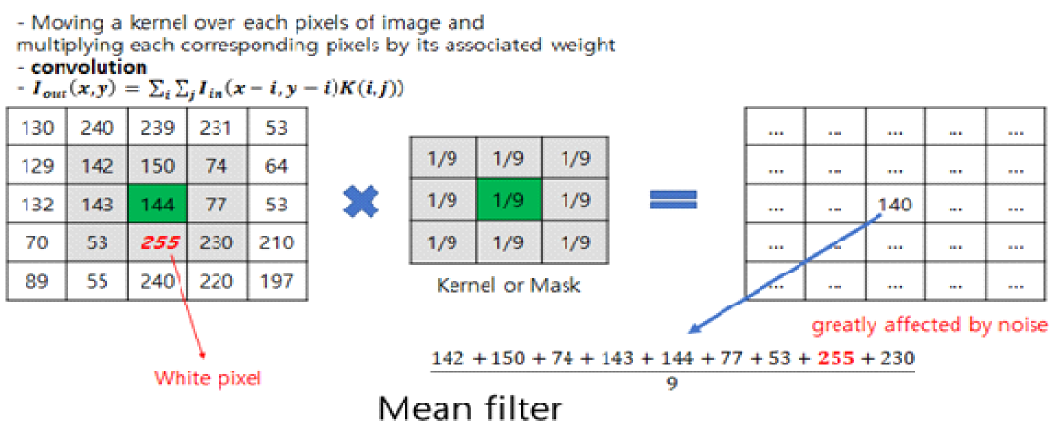

Figure 5: Mean (Average) filter

Average and mean filters use window (mask) to process each pixel in the noisy image in the same manner, this window is fixed and un changeable and it is used to process noisy and not noisy pixels and these will lead to decrease the quality of the obtained de-noised image by decreasing peak signal to noise ratio (PSNR) and increasing the value of mean square error (MSE) between the clear and de-noised images, these quality parameters can be calculated using equations 1 and 2[17], [18].

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

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

Where: f and g are the two images to be compared for quality.

Using fixed and stable window to apply filtering in most filters based on median and mean filters, this leads to the failure of these filters to get rid of noise, especially if its noise ratio is high, by decreasing the value of PSNR and increasing the value of MSE.
To avoid this we can modify either the median or mean filters by using a special window which has the following features:

- The window size is flexible and can be changed from time to time.
- Each pixel has its own window.
- The window must only treat the noisy pixels (with value 0 or 255) keeping other pixel without change.

The window for each pixel can be selected with a size depends of padding factor used to expand the noisy image, so the noisy image must be padded in order to select the necessary window size, figure 6 shows how to pad the noisy image and to select the window (the window is for the pixel with the red color):

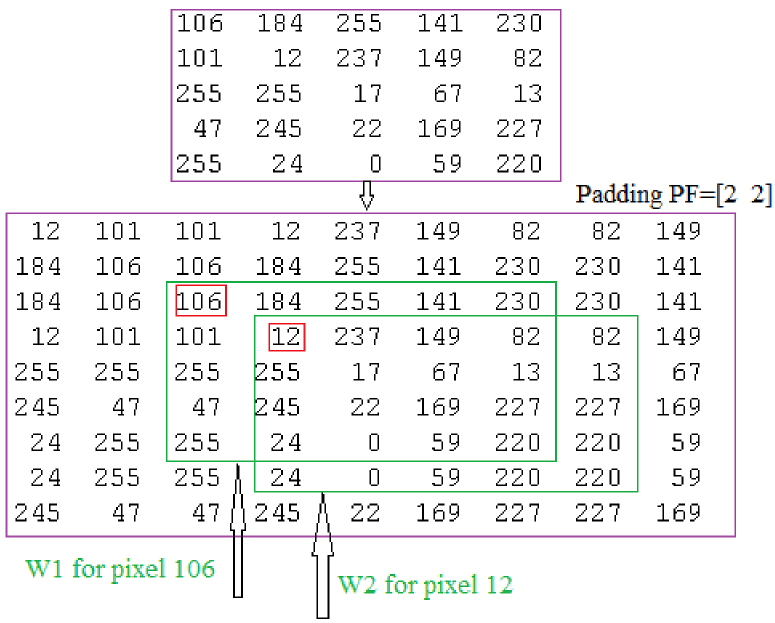

Figure 6: Each pixel has its own window with size 5 by 5

To demonstrate the effectiveness of the proposed modified median filter (MMF) will be compared with the standard median and average filters, it will be also compared with other six popular methods used to reduce 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].

Proposed methodology

Here we introduce a methodology to improve both the median and mean filters to be able to deal with salt and pepper noises with high noise ratios. The methodology is very simple and flexible, it can be used for median or average filters, and the widow size can be change depending on the used choice, (in this paper we use a window of 15 by 15).
The proposed methodology can be implemented applying the following steps:
Step 1: Get the noisy image A.
Step 2: Pad A to a necessary size by selecting the needed value for PF to get the matrix PA.
Step 3: Calculate a zeros-ones matrix for A (ZOA), zero in ZOA means that the associated pixel in A is noisy (0 or 255).
Step 4: Calculate a zeros-ones matrix for PA (ZOPA), see figure 7.

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

ZOA matrix

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

ZOPA matrix

Figure 7: ZO matrices for matrices shown in figure 6

Step 5: Select a window size.
Step 6: for each pixel in A do the following:

- *If the associated pixel in ZOA equal 1 keep this pixel without change and proceed to the next pixel.*
- *Create windows in PA and ZOPA.*
- *If the sum of elements in ZOPA equal zero keep the pixel without change and proceed to the next pixel.*
- *If using median filter replace the pixel with the median of the window elements in PA excluding the value 0s and 255s.*
- *If using average filter replace the pixel with the average of the window elements in PA excluding the value 0s and 255s.*

Implementation and experimental results

In this part we will introduce a comparison analysis of the proposed methodology and the existing average and median filters, and those proposed in [1-6], we will refer to a modified median filter as MMF and to the modified average filter as MAVF, figure 8 shows output calculations of these filters.

NR = 30%

208	25	40	36	167
231	71	248	108	9
32	139	244	234	217
233	244	124	202	238
161	246	204	245	173

Input

255	25	40	36	167
231	71	255	108	255
32	139	244	0	217
255	244	124	0	255
0	255	204	255	173

Noisy

231	71	40	108	167
139	139	71	167	167
231	231	124	217	217
139	204	204	204	217
244	204	244	204	173

Median

112	25	40	36	167
231	71	117	108	48
32	139	244	72	217
112	244	124	112	95
155	140	204	155	173

MAVF

71	25	40	36	167
231	71	71	108	38
32	139	244	40	217
71	244	124	71	71
139	139	204	139	173

MMF

178	133	71	123	151
141	144	102	147	158
166	177	132	162	174
135	166	163	164	172
140	171	200	183	190

Average

Figure 8: Calculation example

3 types of images, small, medium and big size images were selected (see figure 9), the images were noised using various values of NR, then the noisy images were treated using various filters, the obtained results are shown in tables1 thru 4.

Figure 9: Used images with various sizes

Table 1: Results using Average filter

Image	Noise ratio (%)								
	10	20	30	40	50	60	70	80	90
Small	39.4506	36.6552	33.7798	30.9595	28.2948	26.0273	23.8324	21.6261	20.0574
Medium	55.2175	48.2424	43.0495	38.6816	35.2706	29.6100	27.2648	27.1613	25.1806
Big	61.5789	55.3452	50.7335	47.0722	44.0301	41.4166	39.0992	37.0518	35.1915
Average	52.0823	46.7476	42.5209	38.9044	35.8652	32.3513	30.0655	28.6131	26.8098

Table 2: Results using median filter

Image	Noise ratio (%)								
	10	20	30	40	50	60	70	80	90
Small	47.9204	44.6626	39.6221	34.0044	28.4050	23.0761	18.7326	14.5342	11.8832
Medium	74.2805	64.9484	53.0746	41.9478	33.5894	21.4377	17.0901	16.9823	13.6279
Big	81.1011	69.9287	55.8450	44.5526	35.8021	28.9409	23.4961	19.1501	15.6786
Average	67.7673	59.8466	49.5139	40.1683	32.5988	24.4849	19.7729	16.8889	13.7299

Table 3: Results using MAVF

Image	Noise ratio (%)								
	10	20	30	40	50	60	70	80	90
Small	55.6886	51.5497	48.6390	46.5135	45.0129	43.2921	41.5723	40.5743	39.1448
Medium	73.8043	68.4436	64.9214	62.2730	60.1607	58.3415	56.6751	54.9997	52.7649
Big	87.9701	82.0580	78.2721	75.5723	73.3559	71.5111	69.9808	68.4183	66.5614
Average	72.4877	67.3504	63.9442	61.4529	59.5098	57.7149	56.0761	54.6641	52.8237

Table 4: Results using MMF

Image	Noise ratio (%)								
	10	20	30	40	50	60	70	80	90
Small	56.2272	51.4850	48.9809	46.6142	44.4476	42.7609	41.2049	40.4381	38.6458
Medium	75.1751	70.0583	66.5264	64.0119	61.8637	59.7861	58.0038	55.8839	53.1812
Big	88.0562	82.0390	78.4587	75.6982	73.5285	71.7116	70.0029	68.5414	66.5179
Average	73.1528	67.8608	64.6553	62.1081	59.9466	58.0862	56.4039	54.9545	52.7816

From the results shown in tables 1 thru 4 we can see the following:

- The average and median filters failed to get rid of the SAPN, especially when the noise ratio is high and for any image and any size (see values with red colors).

- Average and median filters modifications add significant improvements by enabling the filter to handle noise even when the noise ratio is high, for any image and at any size (see values of green color in tables 3 and 4), the enhancement is shown in figure 10, here MAVF and MMF increase the quality of the de-noised image by increasing PSNR.

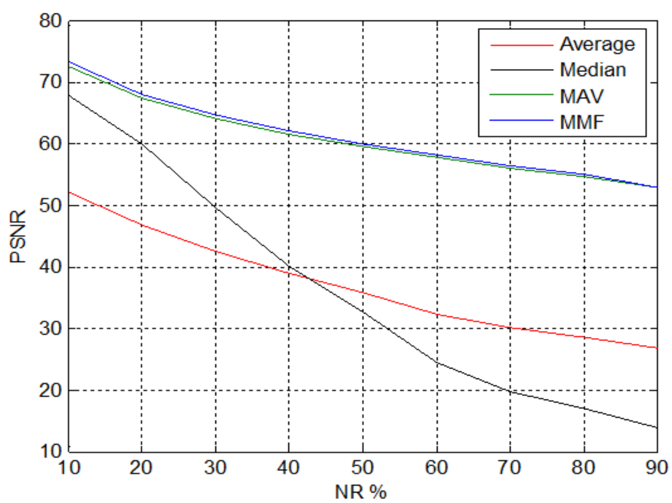

Figure 10: Added enhancement Of MAVF and MMF

Lena.jpg image was noised by salt and pepper noise using various values of NR, the noised images were treated using the previous filter and the filters discussed in [1-6], table 5 shows the results comparisons of the filters.

Table 5: Results comparisons

Method	Noise ratio %								
	10	20	30	40	50	60	70	80	90
SM	36.12	33.42	31.36	29.88	28.54	26.76	24.47	19.52	8.80
DWM	40.78	37.02	34.63	32.51	30.23	27.69	25.23	21.00	15.45
MDWM	41.50	38.13	36.10	34.16	32.62	31.22	29.77	27.94	25.34
MDW	42.71	39.49	37.28	35.41	33.44	31.34	30.35	28.81	26.57
TVW	42.53	39.12	36.92	35.16	33.87	32.29	30.95	29.12	26.84
TSF	43.08	39.87	37.63	35.79	34.02	32.13	31.10	29.45	27.16
Average	55.2175	48.2424	43.0495	38.6816	35.2706	29.6100	27.2648	27.1613	25.1806
Median	74.2805	64.9484	53.0746	41.9478	33.5894	21.4377	17.0901	16.9823	13.6279
MMF	75.1751	70.0583	66.5264	64.0119	61.8637	59.7861	58.0038	55.8839	53.1812
MAVF	73.8043	68.4436	64.9214	62.2730	60.1607	58.3415	56.6751	54.9997	52.7649

And here from table 5 we can see that the best results of de-noising process were achieved by MAVF and MMF filters.

Conclusion

Several filters to reduce salt and pepper noise negative effects were tested using noisy images with high noise ratio. Average and median filters failed to treat such noises, a modifications were added to these filters allowing them to deal and treat noisy image with any size and with any NR value, the filters modification enhances the results of image de-noising by rapidly increasing the quality of the de-noised images by increasing the PSNR values.

The proposed filter with a proposed modification was compared with other popular filters discussed in the literature and the proposed methods gave better results.

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