Smoothing Image using Adaptive Median Filter

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Abstract

Median filter is adopted to match the noise statistics of the degradation seeking good quality smoothing images. Two methods are suggested in this paper(Pentagonal-Hexagonal mask and Scan Window Mask), the study involved modified median filter for improving noise suppression, the modification is considered toward more reliable results. Modification median filter (Pentagonal-Hexagonal mask) was found gave better results (qualitatively and quantitatively) than classical median filters and another suggested method (Scan Window Mask), but this will be on the account of the time required. But sometimes when the noise is line type the cross 3x3 filter preferred to another one Pentagonal-Hexagonal with few variation. Scan Window Mask gave better results qualitatively when removing line noise than another filters, also will be on the account of the time required.

Keywords
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تنعيم الصورة باستخدام مرشح القيمة الوسطى المحور

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الخلاصة:

تبنينا طريقة القيمة الوسطى لإزالة الضوضاء من الصور المضطربة . طريقتان مقترحة لإزالة التشوه من الصور وهي (Pentagonal-Hexagonal mask and Scan Window Mask) الدراسة تضمنت مرشح القيمة الوسطى المحور ، التحوير اخذ بنظر الاعتبار أعطاء دقة نتائج أكثر . طريقة (Pentagonal-Hexagonal mask) أعطت نتائج أفضل مقارنة مع مرشح القيمة الوسطى التقليدي والطريقة المقترحة الأخرىScan Window Mask ولكن تستغرق وقت أطول. أحيانا طريقة cross 3x3 تتفوق على طريقة Pentagonal-Hexagonal بقليل في إزالة الضوضاء من النوعline. أما طريقة Scan Window Mask أعطت نتائج عيا نية أفضل في إزالة الضوضاء من النوع line أيضا تستغرق وقت أطول .

Introduction

Noise in an image generally has a higher spatial frequency spectrum than the normal; image components. Image noise arising from a noisy sensor or channel transmission errors usually appears as discrete isolated pixel variations[1]. Rank filters are designed to operate on a numerically ordered set of pixels. The pixels .P1……PN from the local neighborhood are gathered and sorted into a new set P(1)….P(N) . For grayscale images, the ordering is determined by pixel intensity, but there is no obvious analogue for higher dimensional data such as color pixels. Manipulation of the ordered set of data originated as a way to improve the statistical robustness of traditional estimates (such as the mean) when the data was contaminated .Digital images are often contaminated by noise. Thus, to some, it seemed natural to apply rank techniques to image denoising.. The simplest rank filter is the median filter [2].

Median Filter

A median filter is based upon moving a window over an image (as in a convolution) and computing the output pixel as the median value of the brightnesses within the input window. If the window is j×k in size we can order the j*k pixels in brightness value from smallest to largest . If j*k is odd then the median will be the (j*k+1)/2 entry in the list of ordered brightnesses. A useful variation on the theme of the median filter is the percentile filter. Here the center pixel in the window is replaced not by the 50% (median) brightness value but rather by the P% brightness value where P% ranges from 0% (the minimum filter) to 100% (the maximum filter). Values other then (p=50)% do not , in general, correspond to smoothing filters [3]. Median filtering is a non-linear process, which is useful to reduce certain undesirable type of noise ; i.e. salt & pepper noise .This type of smoothing filter preserves image edges , thus does not causes blurring [4]. A problem with two-dimensional median filtering is that it destroys thin lines as well as isolated points, and it also "clips" corners. We can preserve horizontal and vertical lines or corners by using e.g., a cross-shaped filtering neighborhood such as :

		x		
		x		
x	x	x	x	x
		x		
		x		

In which the value of the center "X" is replaced by the fifth largest of the of the xs, values; but this does not help for diagonally oriented lines or corners .Thus median filtering is best applied to pictures that do not contain thin curves or sharp corners [5].

Objective Measure of an Image Quality

An objective quality measure should well reflects the distortion on the image due to many reasons (e.g., blurring, noise, compression or, turbulence effects). Such measures include the mathematical terms using to compute the similarity degree between images. A good example is the mean-square- error(MSE) over the image array is :

$$MSE = \frac{1}{N^2}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} e^2(x,y) \quad ....(1)$$

$$MSE = \frac{1}{N^2}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}\left[g(x,y) - f(x,y)\right]^2 \quad ....(2)$$

and the Root Mean Square Error(RMSE) is define as :

$$RMSE = \left[\frac{1}{NM}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(g(x,y) - f(x,y)\right)^2\right]^{1/2} \quad ...(3)$$

The values of error measures normalized RMSE (NRMSE) lie between zero (good closeness) and one(different images)[6]. Commonly used objective measures are the root-mean-square error (ERMS), the root-mean-square signal-to-noise ratio (SNRRMS) and the peak signal-to-noise ratio (PSNR). Because related works have used the PSNR, it will be used here for comparison purposes. The PSNR is usually measured in dB and can be defined as

$$PSNR = 10\log_{10}\frac{(L-1)^2}{\frac{1}{N^2}\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[\hat{f}(r,c) - f(r,c)\right]^2} \quad ....(4)$$

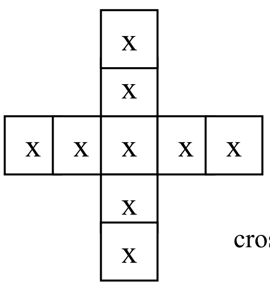
where L is the number of the gray levels, f(r, c) is the original image and $\hat{f}(r,c)$ is the reconstructed image[7]. When PSNR maximum, then the quality of the reconstructed image is good.

Experimental Work and Results

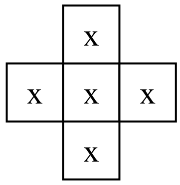
Two test images are used in this experimental study (Ambassadors and Autumn image). Each consists of (260×250)pixels. The noisy image was used with the understanding that some filters may be better suited for specific images and therefore may not be globally best, first amount 12.5% uniform noise was added. Each filter was applied to this image. Next, 12.5% Gaussian noise was introduced each filter was again applied , and corrupted with white lines can be found in the data directory, this test image was used to examine the filter's ability to preserve thin lines and sharp corners. In this paper suggested two methods for removing noise and compare them with conventional median filter, in order to evaluate the performance of the suggested methods.

Conventional Median Filter :

The form of window in conventional median filter is square or rectangular and in different size (3×3,5×5,7×7,………etc) in this paper used 3×3 and 5×5. The main disadvantage of median filtering in a rectangular neighborhood is its damaging of thin lines and sharp corners in the image this can be avoided if another shape of neighborhood is used cross-shaped filtering 3×3 and 5×5 was used in this paper as shown below:



cross-shaped filtering 5×5



cross-shaped filtering 3×3

Suggestion Methods:

First Method (Pentagonal - Hexagonal Mask)

In this method used 5×5 window size .Figure (1a) shows a pentagonal and a hexagonal window, with the pixel (x,y) as a pivot for both windows, each window have seven pixels. In this way take the median of seven values (neighborhood) for each of the pentagonal and a hexagonal windows, finally, obtained eight values can be drawing them with center to get 3 ×3 rectangular window as shown in figure(1b) then take the median of these medians plus the center pixel (x,y) (in this paper this method denoted Pinta-Hexa).

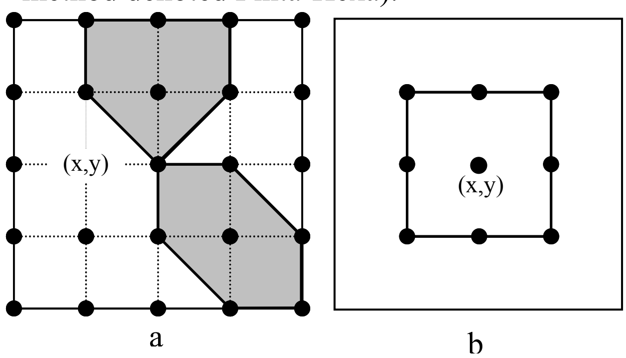
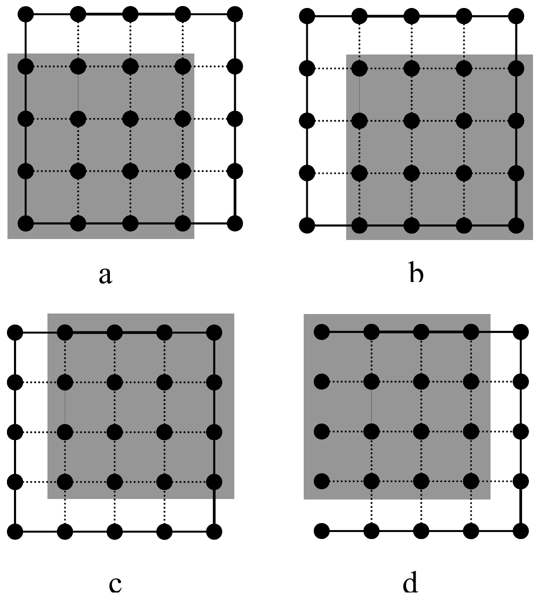


Fig. (1): a- one of the 4 pentagonal windows and one of the 4 hexagonal windows with the pixel to be smoothed (x,y) as a pivot. (b) A 3 by 3 rectangular window given from median of last four Pinta-Hexa windows centered at the pixel (x,y)

Second Method (Scan Window Mask)

In this method also used 5×5 window size ,computing the median for square window after eliminate one row and one column from border, this process repeat forth times, in every case compute the median of square window then compute the median of these medians, with center of 5×5 window(i.e. result of median equal median of a,b,c,d, and center of 5×5 window) as shown in figure (2). Each window have (16) pixels, , this does not give the true median but it may be an acceptable approximation (in this paper this method denoted Scan Window Mask(SWM)).



Figure(2) Illustrated Scan Window Mask (SWM) method

Figures (3,4,5,6,7,8) shown the original images (Ambassadors image and autumn image respectively), noisy images , and smoothed images using the previously filters.

We have studied the effects of the conventional median filters (3×3 rectangular shaped, 5×5 rectangular shaped, 3×3cross-shaped, and 5×5cross-shaped), these filters smooth the data while keeping the small and sharp details, and found that the best performance is that of the cross window, this shows that the filter cross-shaped median has good thin-line preserving. Good results getting when the size of the window chosen to be 3×3 in order to decrease the blurring and for shorter required computer time.

The experimental results have shown that the suggested method (Pinta-Hexa) give results qualitatively and quantitatively better than the conventional median filter for all types of noise (Gaussian , uniform, and line noise). Scan Window Mask(SWM) method qualitatively gives a good results especially for line noise.

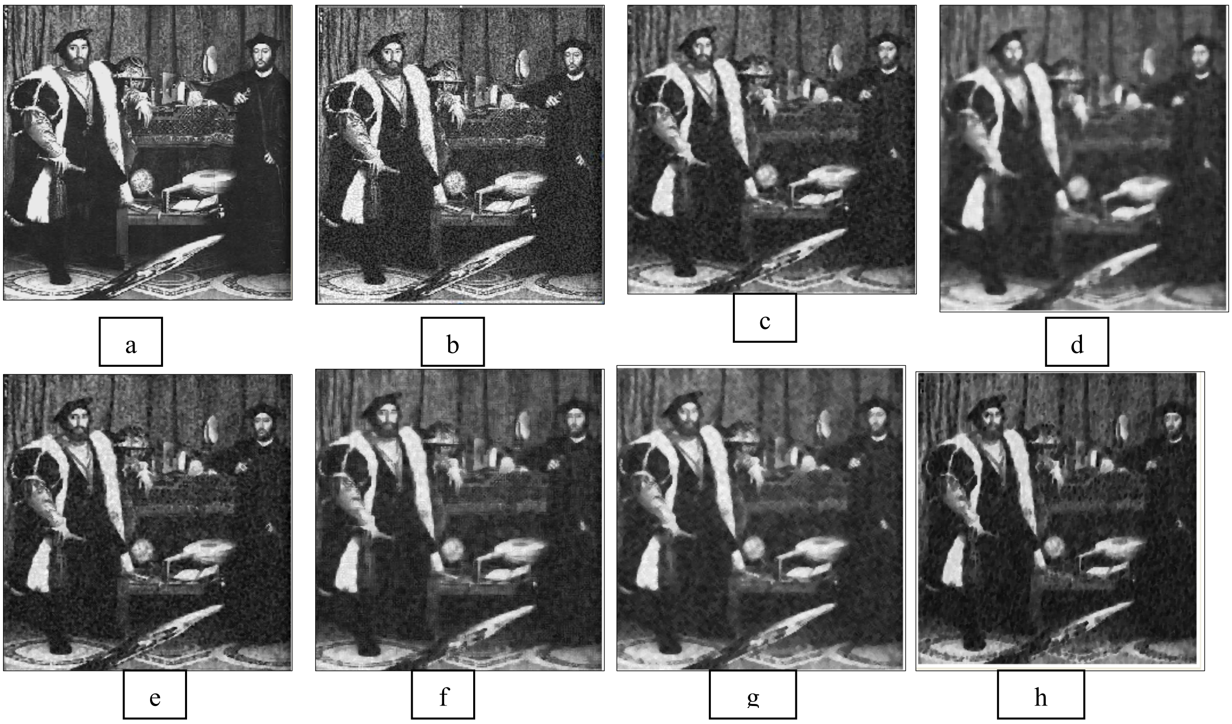
The results obtained from these filters have been compared quantitatively, using the MSE, RMSE, and PSNR as shown in tables (1,2), and qualitatively by demonstrating the output of each filter. Unfortunately, because there is no existed quantitative test which match exactly with what can be visually observed, there was an unsuccessful coincidence between these tests i.e. , good viewed results yield bad quantitative test results and vice versa.

Table (1) The MES, RMSE, and PSNR for conventional and adaptive median filters using Autumn Image.

Type Median	Type Noise	MSE × 10^{-3}	RMSE × 10^{-2}	PSNR
Square 3×3	uniform	0.435	6.600	71.739
Square 5×5		4.615	6.793	71.488
cross 3×3		5.970	7.730	70.366
cross 5×5		4.831	6.950	71.290
Pinta-Hexa		3.653	6.044	72.503
SWM		12.889	11.353	67.028
Square 3×3	Gaussian	6.776	8.232	69.820
Square 5×5		5.453	7.384	70.764
cross 3×3		11.193	10.579	67.641
cross 5×5		72.865	8.535	69.505
Pinta-Hexa		5.083	7.129	71.069
SWM		19.067	13.808	65.327
Square 3×3	Line	2.479	4.979	74.186
Square 5×5		4.055	6.368	72.050
cross 3×3		2.479	4.979	74.299
cross 5×5		2.980	5.459	73.387
Pinta-Hexa		2.564	5.064	74.040
SWM		8.620	9.284	68.775

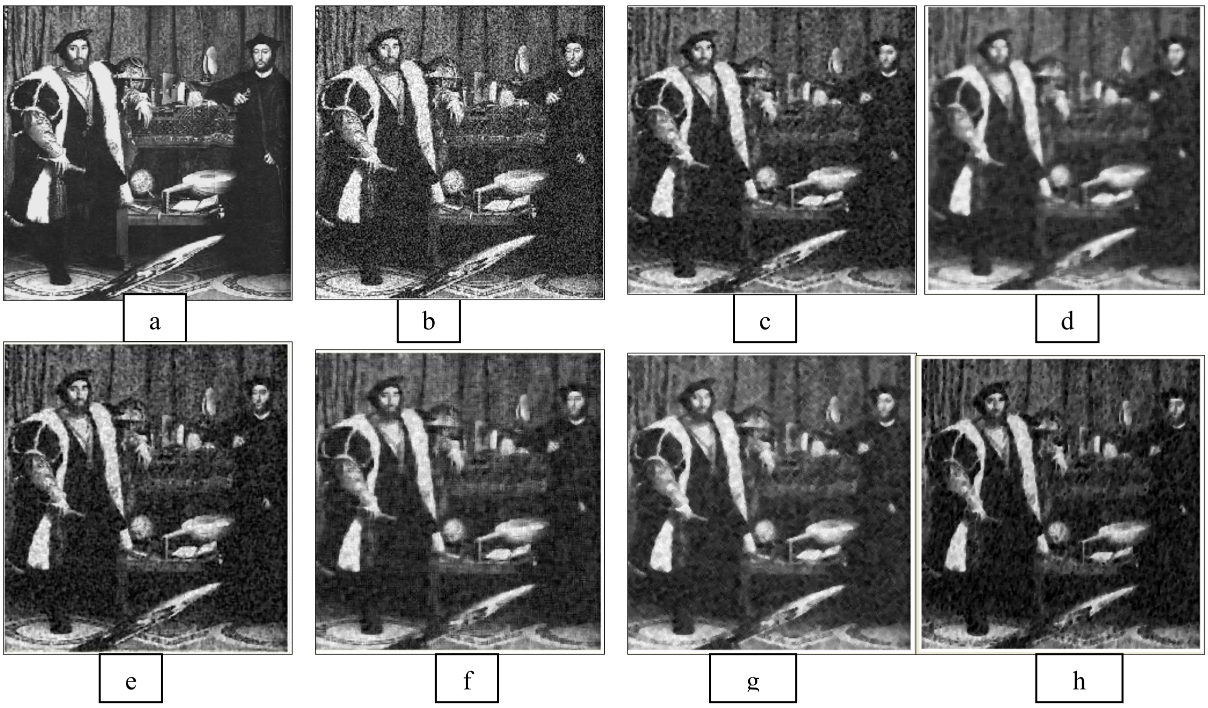
Table (2) The MES, RMSE, and PSNR for conventional and adaptive median filters using Ambassadors Image.

Type Median	Type Noise	MSE × 10^{-2}	RMSE	PSNR
Square 3×3	uniform	1.009	0.100	68.089
Square 5×5		1.201	0.109	67.332
cross 3×3		1.130	0.106	67.597
cross 5×5		1.024	0.101	68.024
Pinta-Hexa		8.422	0.091	68.876
SWM		2.869	0.169	63.552
Square 3×3	Gaussian	1.262	0.1133	67.117
Square 5×5		1.290	0.1135	67.024
cross 3×3		1.672	0.129	65.896
cross 5×5		1.272	0.112	67.083
Pinta-Hexa		0.996	0.098	68.145
SWM		3.547	0.188	62.630
Square 3×3	Line	0.905	0.095	68.562
Square 5×5		1.167	0.108	67.457
cross 3×3		0.872	0.093	68.721
cross 5×5		0.897	0.094	68.598
Pinta-Hexa		0.787	0.088	69.165
SWM		2.532	0.159	64.095



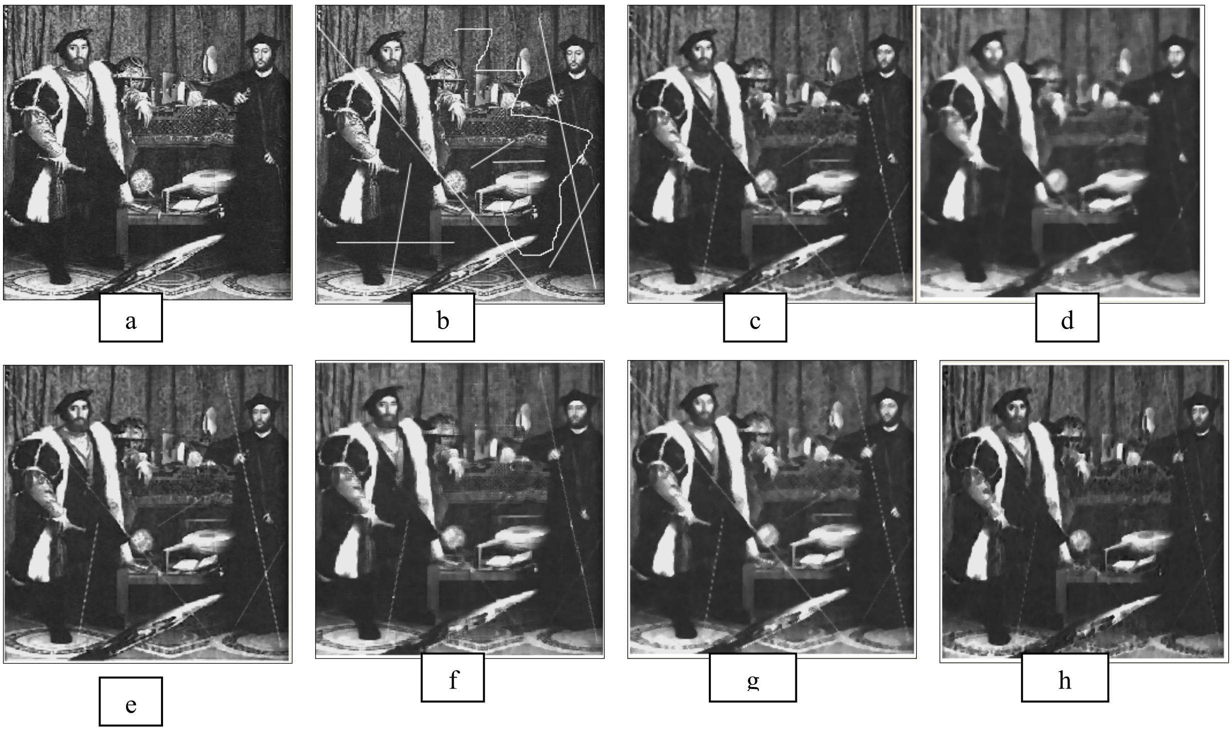
Figure(3)

a-original image (Ambassadors image) b-mage corrupted with uniform noise c-result of 3×3 square median filter d- result of 5×5 square median filter e- result of 3×3 cross median filter f- result of 5×5 cross median filter g- result of Pinta-Hexa median filter h- result of SWM filter .



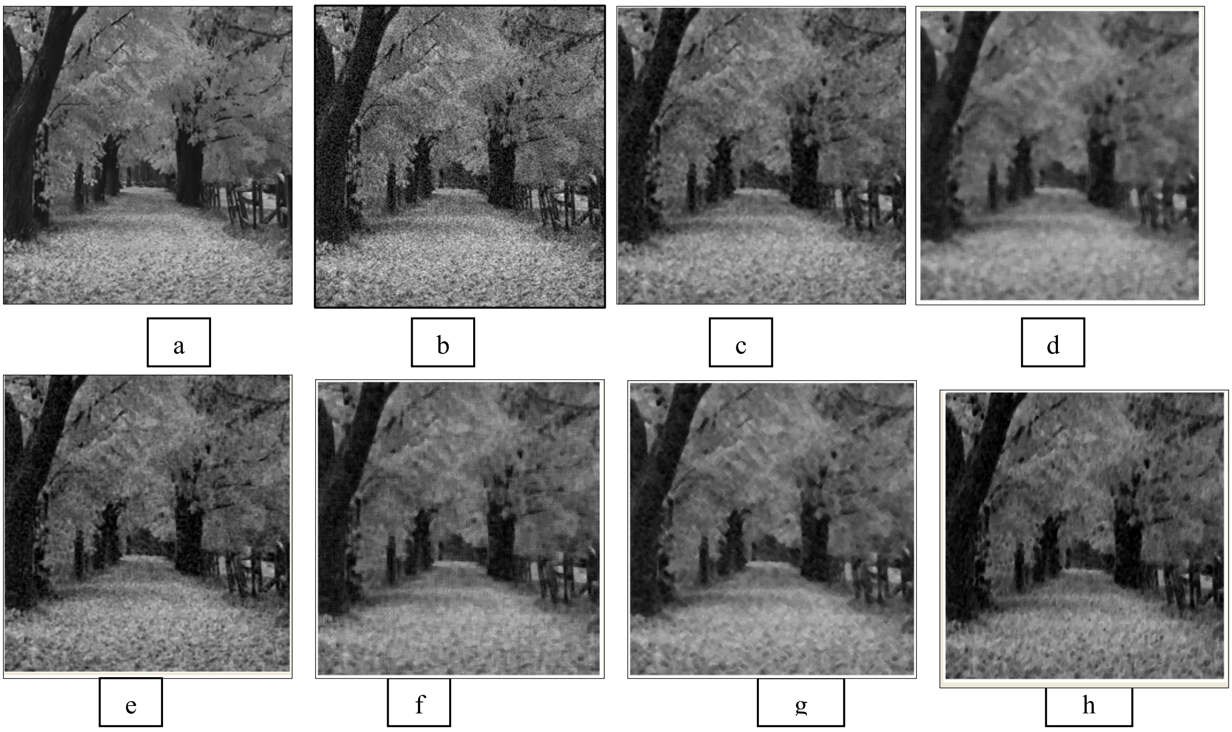
Figure(4)

a-original image(Ambassadors image) b- image corrupted with Gaussian noise c-result of 3×3 square median filter d- result of 5×5 square median filter e- result of 3×3 cross median filter f- result of 5×5 cross median filter g- result of Pinta-Hexa median filter h- result of SWM filter .



Figure(5)

a-original image(Ambassadors image) b- image corrupted with line noise c-result of 3×3 square median filter d- result of 5×5 square median filter e- result of 3×3 cross median filter f- result of 5×5 cross median filter g- result of Pinta-Hexa median filter h- result of SWM filter .

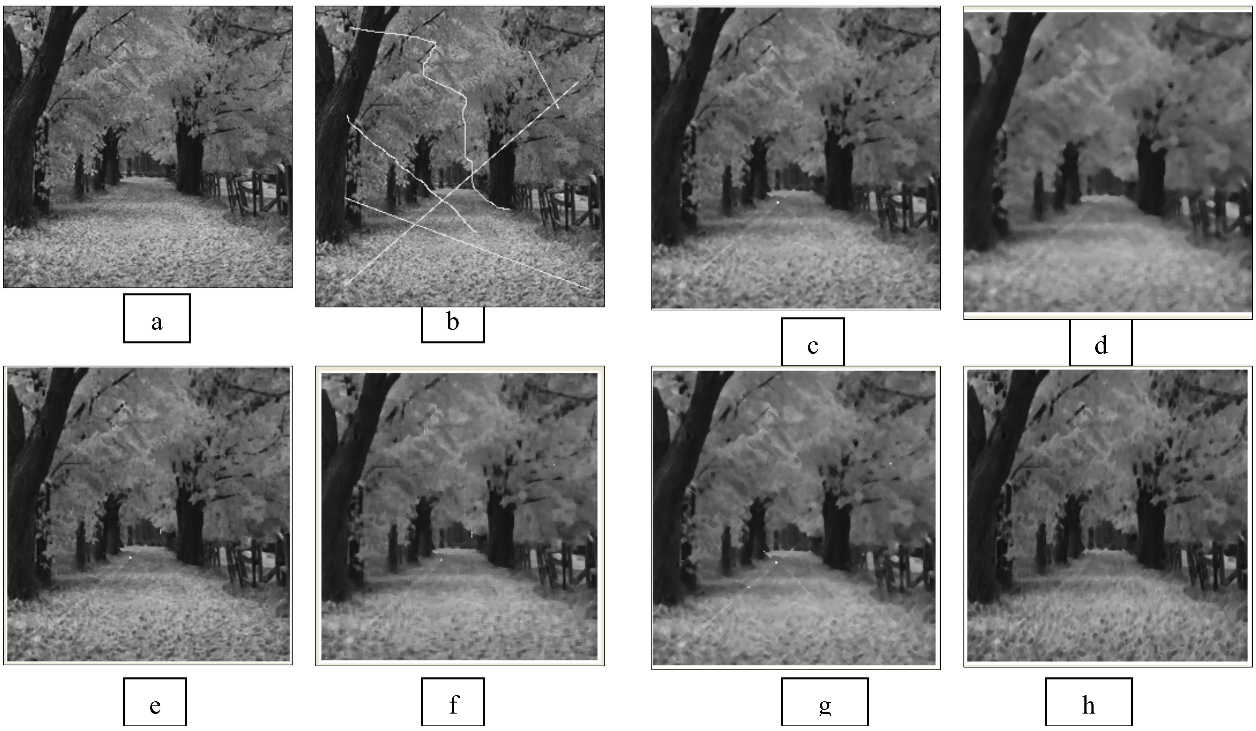


Figure(6)

a-original image(Autumn image) b- image corrupted with uniform noise c-result of 3×3 square median filter d- result of 5×5 square median filter e- result of 3×3 cross median filter f- result of 5×5 cross median filter g- result of Pinta-Hexa median filter h- result of SWM filter.

Figure(7)

a-original image(Autumn image) b- image corrupted with Gaussian noise c-result of 3×3 square median filter d- result of 5×5 square median filter e- result of 3×3 cross median filter f- result of 5×5 cross median filter g-result of Pinta-Hexa median filter h- result of - result of SWM filter .



Figure(8)

a-original image(Autumn image) b- image corrupted with line noise c-result of 3×3 square median filter d-result of 5×5 square median filter e- result of 3×3 cross median filter f- result of 5×5 cross median filter g-result of Pinta-Hexa median filter h- result of SWM filter .

Conclusions

When compare the classical method with the modified methods and depending on the previous results can conclude:

1- The Modification median filter (Pentagonal-Hexagonal mask) was found gave better results comparison with classical median filters, but this will be on the account of the time required. But sometimes when the noise is line type the cross 3x3 filter preferred to another one pentagonal-Hexagonal with few variation as like in table (1).

2- The Modification median filter(Scan Window Mask(SWM)) gave results qualitatively when removing line noise better than another filters.

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