Comparative Analysis Of Various Filtering Techniques In Image Processing

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Abstract: Denoising images is an important task in image processing. Images contain noise while capturing and transmission of images. To improve the image quality, the denoising technique is applied to improve the quality of the image which is passed through filters. Some of the noises are applied to the LENA image which is used for the experimentation. The performance of the filters are measured using Peak Signal to Noise Ratio(PSNR), Normalized Mean Square Error (NMSE) and Elapsed Time (ET). At the end of the experimentation result, the best filter technique is found.

Keywords: Noises, Filters, PSNR, NMSE, Elapsed Time.

1. Introduction

A digital image is a finite set of digital values and consists of a fixed number of pixels [9]. The most important task in image processing is to clear the noise from the noisy images. The various noise removal techniques are used to preserve the important characteristics of images which are corrupted due to noises [2]. It would be always useful in several fields related to simulation but particularly in medical field which provides the accurate results. The four types of filters are studied and the performance of these filters are evaluated in this paper.

2. Noises

Due to the environmental conditions or camera imperfections, Images are corrupted by random variations in intensity values. Some errors may occur while capturing an image or transmitting an image. Some of the noises such as Salt & Pepper, Gaussian, Poisson and Speckle are discussed in this paper.

2.1 Salt & Pepper Noise

Mostly Salt & Pepper noise occurs due to the disturbances happened in the image pixels. In this type of noise, white and black pixels are sparsely found on the image. Median filter can be used to clear either salt noise or pepper noise, but not both. The malfunctioning of pixel elements in camera sensors, faulty memory space in storage and errors in digitization process corrupts the digital image and causes the salt & pepper noise [4].

2.2 Gaussian Noise

Gaussian noise is familiar with digital images and they arise due to poor lighting or high temperature or transmission [4]. Spatial filter can be used, but cannot assure the complete clearance. While reducing the gaussian noise using spatial filter, the fine scaled image details are also reduced. The grey values in digital images are also disturbed by the gaussian noise.

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2.3 Poisson Noise

Poisson noise is also called as shot noise or photon noise which occurs in optical devices. When photon counting increases the nature of light gets changed. This noise leads to the high brightness of the image [7]. The statistical nature of electromagnetic waves such as x-rays and gamma rays produce this type of noise.

2.4 Speckle Noise

Speckle occurs due to the random fluctuations of signals which results in the increased grey level of the image. It is a multiplicative noise that is found in coherent imaging systems [13]. The random interference between the coherent returns produces this noise. It degrades the quality of the image. The mean grey level of a local area is increased by this noise.

3. Filters

Filtering means replacing each pixel intensity value with a new value taken over a neighbourhood of fixed size. The images which are often corrupted by random variations in intensity and illumination should be passed on to the filters [14]. Filters transform the pixel intensity values to reveal certain image characteristics like enhancement and smoothing. Filters remove some frequencies and also reduce background noise [3]. The various filters applied on the noisy image are discussed below.

3.1 Median Filter

Median filter is more often used to remove noise from an image or signal which is widely used for a specific reason.It preserves edges while removing noise [16]. Mainly median filter is used in signal processing and time series processing. The effect of input noise values with extremely large magnitudes can be eliminated by this type of filters.

3.2 Gaussian Filter

Gaussian filter is widely used in graphics software which reduces the image noise by blurring an image [4]. It acts as a smoothing operator and mainly used in research areas. The probability distribution for noise is defined by the gaussian function. The image structures can be enhanced by gaussian smoothing.

3.3 Wiener Filter

Wiener filter minimizes the noise by estimating the target and desired process. It reduces the square error between the target and desired process. The noise that corrupts the

signal is filtered by the wiener filter [6]. The additive noise is removed and the blurring is inverted simultaneously using this filter.

3.4 Average filter

Average filter is the most popular filter in improving noisy images. It reduces the sharpness and flattens the local differences [10]. It replaces each pixel by the average of pixels in a square window surrounding that particular pixel. This filter can effectively remove the noise but the edges are blurred.

4. Performance Metrics

Each and every noisy image is passed on to the four specified filters and produces different resultant images. The results received from the various filters are different so that the best filter is not found simply by seeing the resultant images. Thus the performance of the four filters is measured using Peak Signal to Noise Ratio (PSNR), Normalized Mean Square Error (NMSE) and Elapsed Time (ET) using MATLAB. To measure the image quality metrics and their analysis, MATLAB is used [11].

4.1 PSNR

PSNR is represented as the ratio of maximum power in the image to the corrupted noise in the image [12]. The unit of PSNR is db (decibels). If the PSNR value is higher, then the quality of the filtered image will be good [8]. The formula to calculate PSNR is

$PSNR = 10 \times log_{10}\left(\frac{p^2}{MSE}\right)$ where p is the maximum variation in the input image and MSE is Mean Square Error.

4.2 NMSE

The mean of a series against the predicted values is compared using NMSE. If the value of NMSE is greater than 1, then the predictions are going worse than the series mean and vice versa [15]. The formula to calculate NMSE is

$$NMSE = \frac{\sum_{i=-N/2}^{N/2}\sum_{j=-N/2}^{N/2}[f(i,j)-g(i,j)]^2}{\sum_{i=-N/2}^{N/2}\sum_{j=-N/2}^{N/2}f(i,j)^2}$$

where f(i, j) is the original image with size N*N, and g(i, j) is the filtered image with size N*N.

4.3 ET

The elapsed time is the time taken by each filter to clear the noise from the image [1]. The time starts from inserting the image into the filter and ends its counting when the output image is displayed. The elapsed time is measured in Seconds using MATLAB.

5. Experimental Results

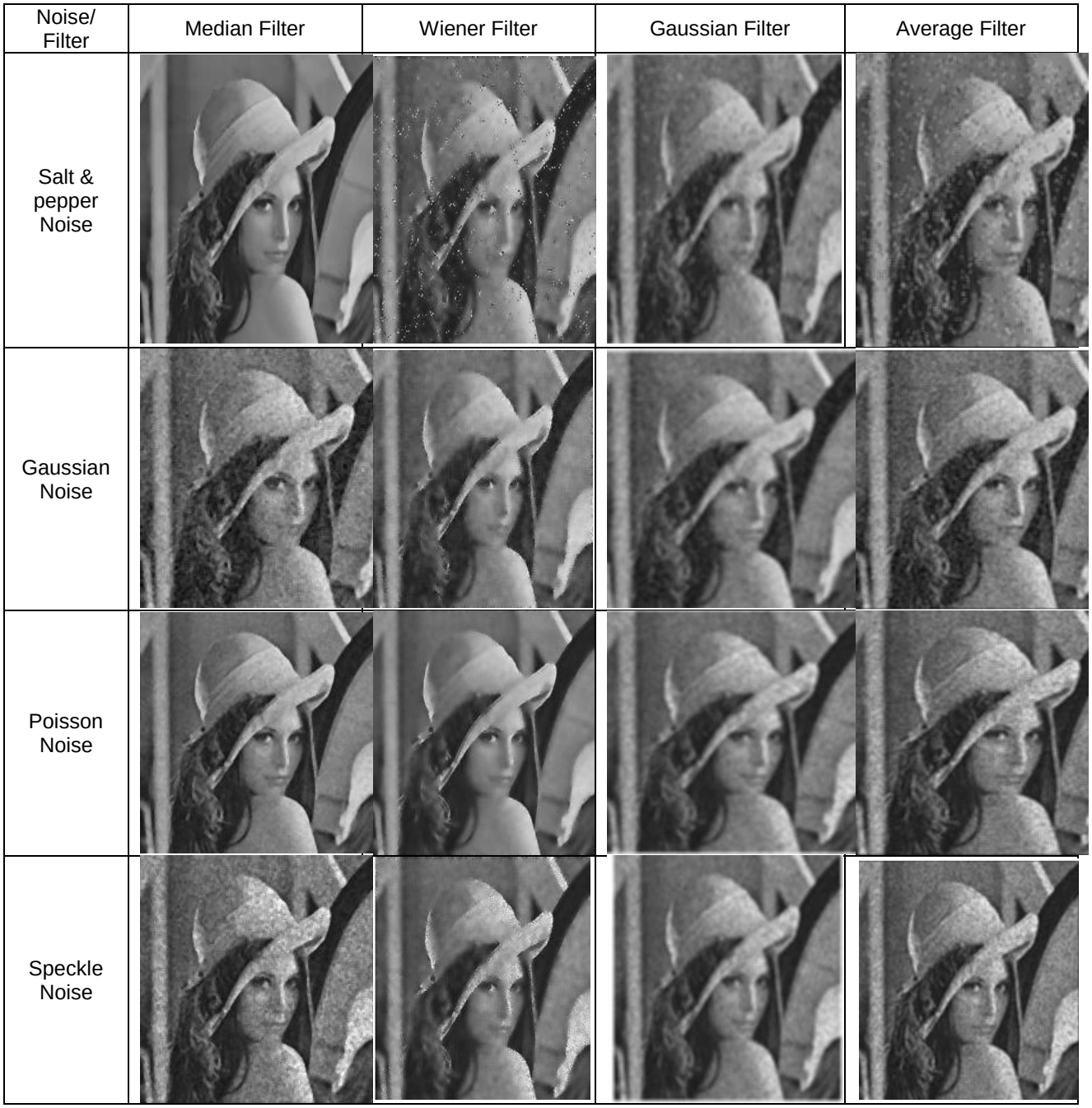
The performance evaluation of different filters using PSNR, NMSE and elapsed time are tested on the LENA image with the help of MATLAB. The various noises are added into the LENA image.

	Salt & pepper	Gaussian	Poisson	Speckle
Noisy images				

Figure.1 *LENA image with different noises*

The LENA image with different noises such as Salt & Pepper, Gaussian, Poisson and Speckle are shown in Figure.1. Each and every noisy image is applied through the four filters such as Median, Gaussian, Wiener and Average. The resultant images are tabulated and presented in Figure.2. The performances of the filters are evaluated by computing PSNR, NMSE and elapsed time. The experimental results are shown in Table.1, Table.2 and Table.3 respectively. The same filter techniques can be applied to various image databases like LI dataset [5] and the expected results can be received.

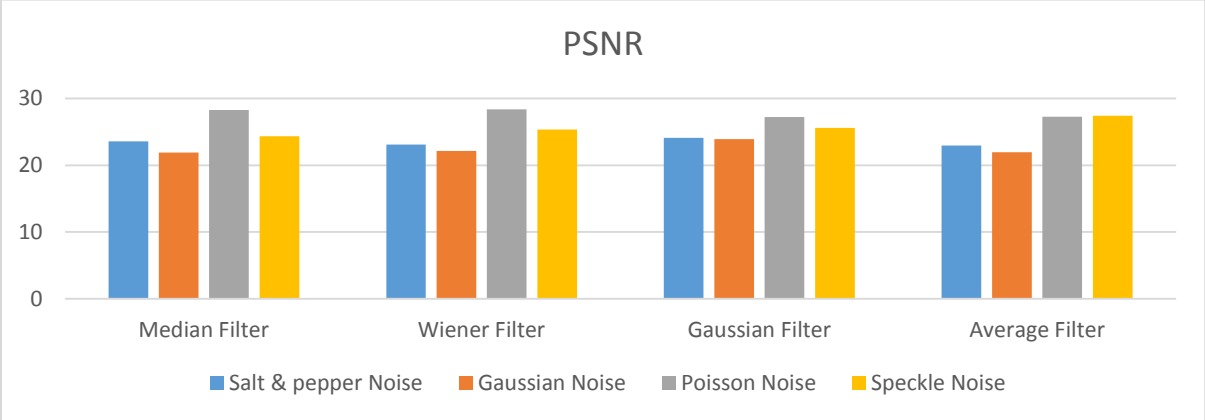
Figure.2 *Filtered Images*



The Table.1 displays the tabulation of the PSNR values calculated for the noisy images filtered through the four specified filters and the chart shows the graphical representation of the PSNR tabulation.

Noise / Filter	Median Filter	Wiener Filter	Gaussian Filter	Average Filter
Salt & pepperNoise	23.5946	23.1126	24.0991	22.9769
Gaussian Noise	21.8892	22.1543	23.9029	21.9376
Poisson Noise	28.2621	28.3680	27.2233	27.2636
Speckle Noise	24.3549	25.3534	25.5878	27.3960

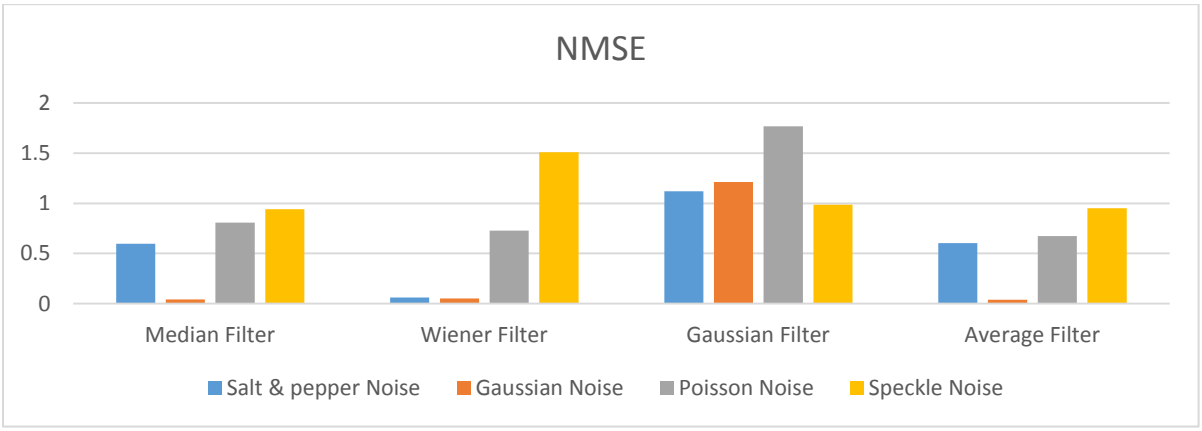
Table.1 *PSNR values of various filters*



The Table.2 displays the tabulation of the NMSE values calculated for the noisy images filtered through the four specified filters and the chart shows the graphical representation of the NMSE tabulation.

Noise / Filter	Median Filter	Wiener Filter	Gaussian Filter	Average Filter
Salt & pepperNoise	0.5971	0.0609	1.1198	0.6027
Gaussian Noise	0.0401	0.0524	1.2119	0.0375
Poisson Noise	0.8086	0.7265	1.7682	0.6744
Speckle Noise	0.9401	1.5105	0.9847	0.9502

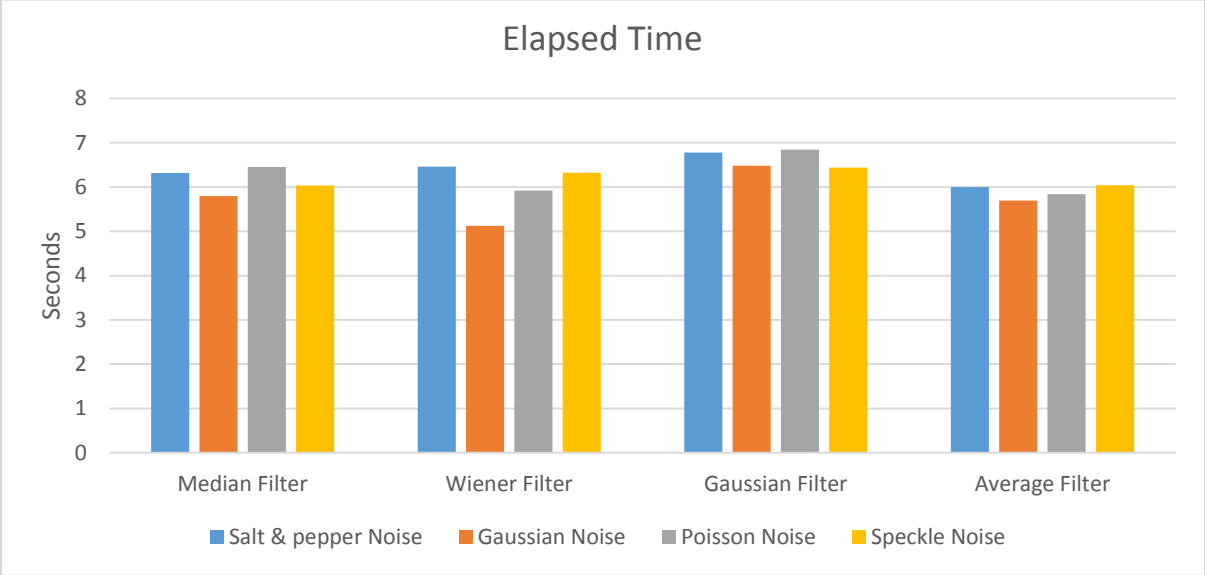
Table.2 *NMSE values of various filters*



The Table.3 displays the tabulation of the elapsed time calculated for the noisy images filtered through the four specified filters and the chart shows the graphical representation of the elapsed time tabulation.

Noise / Filter	Median Filter	Wiener Filter	Gaussian Filter	Average Filter
Salt & pepperNoise	6.317349	6.464153	6.781272	5.996620
Gaussian Noise	5.797709	5.127686	6.482329	5.698020
Poisson Noise	6.450629	5.920701	6.846422	5.836726
Speckle Noise	6.032683	6.326869	6.441321	6.040293

Table.3 *Elapsed time of various filters*



6. Conclusion

In this paper, four types of noises such as Salt & Pepper, Speckle, Poisson and Gaussian are applied to the LENA Image. Then the four filters such as Median, Wiener, Gaussian and Average are applied on the noisy images. The Performance of the filters are measured in terms of PSNR, NMSE and ET metrics. The maximum PSNR is received in Average filter while filtering Poisson noise and Speckle noise. The gradual result is received from Gaussian filter while filtering all the other noises. The maximum NMSE is received by Gaussian filter in clearing Poisson noise and the minimum NMSE is received Average filter in clearing Gaussian noise. The wiener filter is considered to be the best in elapsed time regarding Gaussian noise but Average filter takes very less time in clearing Average, Gaussian and Poisson noises.

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