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Various Image Noises and Its Reduction Techniques

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Abstract

An image may be contaminated with the noise and interference from several sources. For implementing various image processing techniques our image should be free from the noise, therefore Noise reduction is one of the important process in the Digital Image processing. In this paper we are present the image noises present in the digital image and various filtering techniques for cleaning these noises. We added some fixed amount of noises to an image and filtered it out using various filter and plot a graph of result obtained to analyze the performance of the filters.

Keywords: *detector noise, speckle noise, average filter, outlier technique*

1. Introduction

Noise can be introduced into a digital image in many ways starting with the lens of imaging hardware and ending at the digitization of captured image [1]. Generally the brightness of image should be uniform except where it change to form an image there are factor however that tend to produce variation is usually random has no particular pattern . In many and cases, it reduces image quality and especially significant when the object being imaged are small and have relatively low contrast. This random variation in image brightness is designated noise [2]. Image filtering is smoothing of image. Image may get contaminated with noise during acquisition and transmission. The two additive noises are Gaussian noise and Salt and Pepper noise, the basic requirement in image denoising is to minimize these additive noise without affecting the features of the image. Pixels that contaminated with noise looks different than its neighboring pixel. When an image is acquired by a camera or other imaging system, often the vision system for which it is intended is unable to use it directly. The image may be corrupted by random variations in intensity, variations in illumination, or poor contrast that must be dealt with in the early stages of vision processing.

1.1 Types of noises:

Image with the original specifications is given below. And following type of noises are get contaminated with digital images:

Fig. 1: Original Image

1.1.1 Detector noise:

One kind of noise which occurs in all recorded images to a certain extent is detector noise. It is also called as shot noise. This kind of noise mixed because of discrete nature of radiation [4]. Allowing some assumptions this noise can be modelled with an independent, additive model, where the noise n (i, j) has a zero-mean Gaussian distribution described by its standard deviation (σ), or variance. This means that each pixel in the noisy image is the sum of the true pixel value and a random, Gaussian distributed noise value.

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1.1.2 Gaussian Noise:

Gaussian noise is additive noise. However, it must be kept in mind that when smoothing.an image, we reduce not only the noise, but also the fine-scaled image details because they also correspond to blocked high frequencies. The Gaussian noise has a normal (Gaussian) probability density function. Approximately 70% of the values are contained between $\mu \pm \sigma$ and 90% of the values are contained between $\mu \pm 2\sigma$ Although, theoretically speaking, the PDF is non-zero everywhere between $\infty$and ∞it is customary to consider the function 0 beyond $\mu \pm 3\sigma$Gaussian noise is useful for modelling natural processes which introduce noise.

Fig. 2: Image Contaminated with Gaussian Noise

1.1.3 Salt and pepper noise:

It is also called as noise impulse, other terms used for this noise are random noise, independent noise spike noise. Due to this noise we black and whites dot are appears in the images hence called as salt and pepper noise. This noise arises in the image because of sharp and sudden changes of image signal. The salt & pepper noise is generally caused by malfunctioning of camera's sensor cells, by memory cell failure or by synchronization errors in the image digitizing or transmission. Salt and pepper noise is generally is digitized as an extreme value in an image. An image having this type of noise will have dark pixel in bright region and bright pixel dark region. This may cause due to analog to digital converter error, bit error in transmission.

Fig. 3: Image Contaminated with Salt and Pepper Noise

1.1.4 Poisson Noise:

Poisson or shot photon noise is the noise that can cause, when number of photons sensed by the sensor is not sufficient to provide detectable statistical information [5]. This noise has root mean square value proportional to square root intensity of the image. Different pixels are suffered by independent noise values. At practical grounds the photon noise and other sensor based noise corrupt the signal at different proportions.

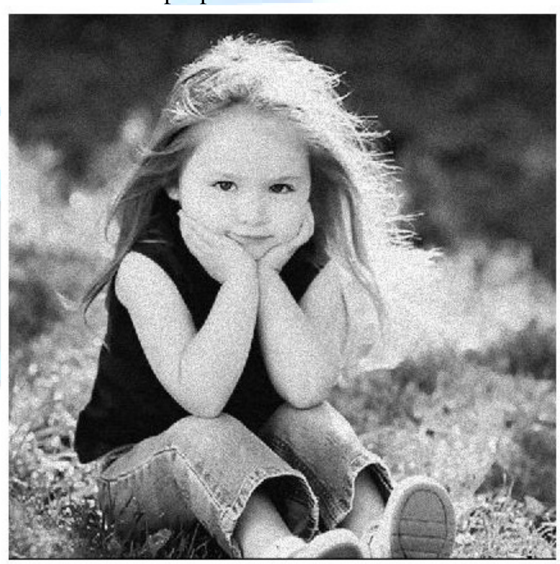

Fig. 4: Image Contaminated with Poisson Noise

1.1.5 Speckle Noise:

This noise generally found in radar imaging, it detoriates the active radar images quality. Due to the coherent processing of back scattered signals from multiple distributed points. In conventional radar system this type of noise is noticed when the returned signal from the object having size less than or equal to a single image processing unit, shows sudden fluctuations.

Fig. 5: Image Contaminated with Speckle Noise

2. Noise Cleaning

The noise effects can be reduced by classical statistical filtering techniques. Image noise generated from a noisy or faulty sensor usually appears as discrete isolated pixel variations that are not spatially correlated. Pixels that are in error often appear visually to be markedly different from their neighbors. This observation is the basis of many noise cleaning algorithms [6]. Gaussian noise can be reduced using average filter and median filter. The most effective basic spatial filtering techniques for noise removal include: mean filtering, median filtering and Gaussian smoothing. Speckle noise can be filtered efficiently using mean/average filter. Noise cleaning further divide into two type as specified as below.

1. Linear Noise Cleaning.
2. Non-Linear Noise Cleaning.

2.1 Linear Noise Cleaning:

Noise added to an image generally has a high frequency component than the normal image component because of its spatial decor relatedness. Hence simple low pass filtering is suitable for noise cleaning.

2.1.1 Spatial Domain Filtering:

A spatially filtered output image can be obtained by convolution of an input image f(x, y) with L*L impulse response array h(x, y) by following equation-

$$G(x, y) = \sum\sum F(m,n)H(m+x+c, n+y+c) \qquad (1)$$

Where $c=\frac{(L+1)}{2}$

For noise cleaning H should be of low pass form with all positive element. The low pass filtering concept can be further extended to larger impulse response array, i.e. we can use 5*5 array instead of 3*3. The use of larger response array provide more noise smoothing but we loss of fine image details too.

2.1.2 Fourier Domain Filtering:

High frequency noise can be reduced by Fourier domain filtering with zonal low pass filter. The ringing artifact are formed due to the sharp cut-off characteristics of zonal low pass filter. This can be remove by using smooth cut-off filters. Unlike convolution, Fourier domain processing often provide a quantitative and intuitive insight into the nature of the noise process, which is useful in designing noise cleaning spatial filters.

2.1.3 Homomorphic Filtering:

For image containing multicative noise or interference this homomorphic filtering is used. Consider an image *f(x, y)* is assumed to be modelled as the product of noise free image *p(x, y)* and illumination interference array *q(x, y)* [6]. Thus

$$F(x, y) = q(x, y)\, p(x, y) \qquad (2)$$

If we take log of above equation it yield additive linear result

$$Log\{f(x, y)\} = Log\{q(x, y)\} + Log\{p(x, y)\} \qquad (3)$$

Now we can apply the conventional linear filtering techniques to reduce log interference component. Exponentiation after filtering completes the enhancement.

2.2 Non Linear Noise Cleaning:

The nonlinear technique often provides a better trade-off between noise smoothing and the retention of fine image details several nonlinear techniques are discuss below.

2.2.1 Outlier technique:

The following equation describe the simple outlier noise cleaning technique in which each pixel compared to the average of its eight neighbor.

If $[x-\frac{1}{8}\sum_{i=0}^{8} O_i\,] > \epsilon$ Then

$$x=\frac{1}{8}\sum_{i=0}^{8} O_i \qquad (4)$$

If the magnitude of difference is exceed some threshold value that pixel is consider as noisy and it replace by neighborhood average. The outlier operator can be extended straightforwardly to larger windows.

Fig. 6: Image Filtered with Order Statistical Filter

Median Filter:

Median filtering is a nonlinear filter. Median filter is effective in reduction of noises like speckle noise, salt & pepper noise and Gaussian too. It superior than order filter and inferior than average filter. It is also useful in preserving edges in an image while reducing random noise. Impulsive or salt-and pepper noise can occur due to a random bit error in a communication channel. In a median filter, we arrange the intensity value in non-increasing order and mid value of the series of intensity values is assigned to target pixel. Following figure shows how median filtering is done.

Average Filter:

Mean filtering is a simple, intuitive and easy to implement method of smoothing images, *i.e.* reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images. The idea of mean filtering is simply to replace each pixel value in an image with the mean value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. Mean filtering is usually thought of as a convolution filter

Order statistical filter:

To apply an order statistic filter to an image, one typically uses 3x3, 5x5 or 7x7 windows. For non-Gaussian noise, the optimal OSF is superior to taking a local average for flat regions. The main problem with such filters is the underlying stationary assumption: the derivation of the OSF assumes that *X* is a stationary point process, an assumption which is grossly violated if there is an edge, line, or other strong signal activity in the window. These limitations motivated the development of the Adaptive Trimmed Mean Filter, which makes the assumption that the signal is smoothly varying within the local window. When the signal varies slowly within the window, the filter behaves like a trimmed mean. When an abrupt transition is detected, the filter behaves like a median, which preserves edges. Unfortunately, the median filter also destroys fine details.

3. Noise analysis

For understanding the image noise and its reduction techniques we perform experiment on image 'cute_girl.tif' in MATLAB. We add noises to it in a fixed interval of 0.1, then using average filter, median filter and order filter we filter the image and calculate the mean square error value between the original image and filtered image. The results is shown in table below. The noises added are Gaussian noise, salt & pepper noise and speckle noise.

$$MSE=\frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2 \qquad (5)$$

For Gaussian Noise:

Table 1: MSE comparison between different filters

Amount of Noise added (%)	MSE-1 (Average Filter)	MSE-2 (Median Filter)	MSE-3 (Order Filter)
0.1	693.52	761.53	921.57
0.15	1386.76	1510.57	740.51
0.2	2302.35	2476.62	866.84
0.25	3393.71	3600.18	1298.61
0.3	4625.05	4853.9	1988.43
0.35	5968.07	6221.65	2835.87
0.4	7390.29	7678.87	3956.17
0.45	8883.45	9187.71	5160.65
0.5	10431.13	10737.26	6515.22

Chart 1 shows the graph plot between the M.S.E. and amount of noises added to the original image for Gaussian noise. From this graph we observe that order filter reduces the Gaussian noise more efficiently than the other two filters. Median filter and average filter are also good for cleaning Gaussian noise. The window used in order filter is 3*3 window.

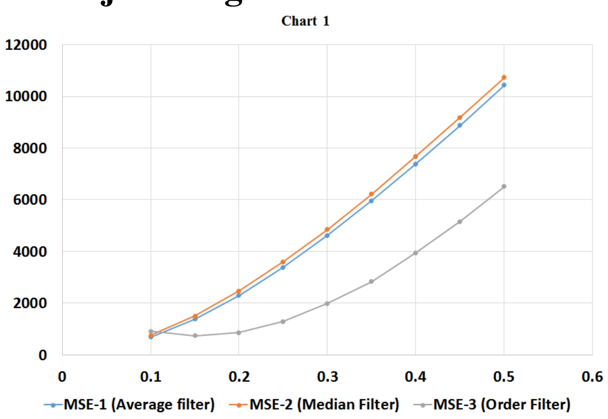

Fig. 7: Graph for Speckle Noise

For Salt & Pepper Noise

Amount of Noise added (%)	MSE1 (Average Filter)	MSE2 (Median Filter)	MSE3 (Order Filter)
0.1	330.94	35.48	1949.87
0.15	509.7	52.05	4769.76
0.2	711.1	94.55	9730.4
0.25	930.88	164.21	15077.12
0.3	1166.09	302.32	18619.7
0.35	1413.87	546.84	20107.67
0.4	1721.92	906.44	20678.89
0.45	2038.44	1470.42	20833.21

Table 2: MSE comparison between different filters

Chart 2 shows the graph for salt &pepper noise. For this noise the median filter is best for noise reduction. It provides better noise reduction than average and order filter. The performance of order filter is better as compare to reduction of Gaussian noise but it is inferior than other two filter. The performance of Average filter and Median filter is somehow same.

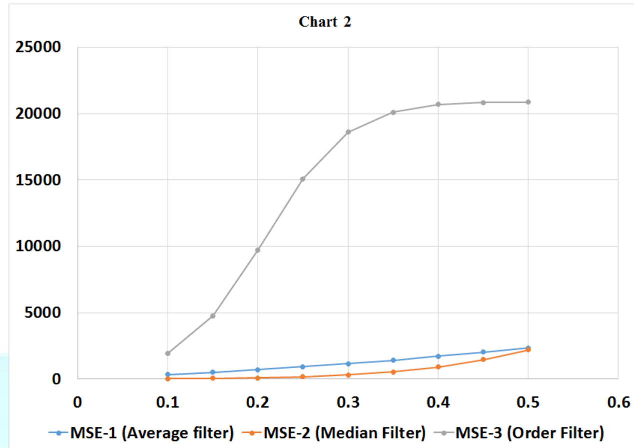

Fig. 8: Graph for Speckle Noise

Chart 3 show the graph of MSE vs amount of noise added for the speckle noise. In this graph also we seen that the Average filter and Median filter reduce the noise efficiently. The median filter is also good so we can used median filter for speckle noise reduction. As usual the order filter is not at all suitable for removing speckle noise.

Table 1: MSE comparison between different filters

Amount of Noise added (%)	MSE-1 (Average Filter)	MSE-2 (Median Filter)	MSE-3 (Order Filter)
0.1	268.72	535.85	4715.39
0.15	390.47	759.72	6437.49
0.2	521.93	977.55	8362.18
0.25	654.39	1187.3	10138.25
0.3	805.34	1379.03	12008.47
0.35	936.91	1572.85	13857.86
0.4	1072.01	1773.07	15681.34
0.45	1158.64	1952.58	17474.39
0.5	1273.93	2155.22	18807.63

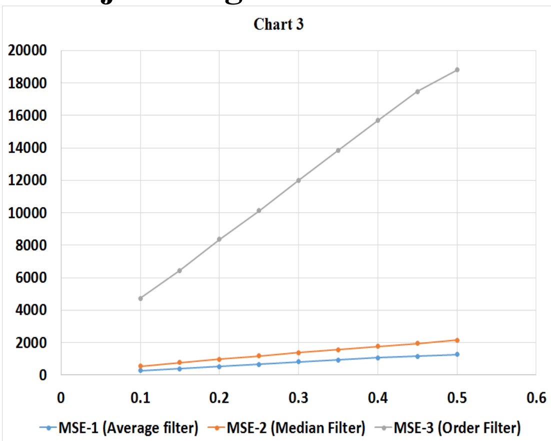

Fig. 9: Graph for Speckle Noise

From this experiment we understand that we can reduce Gaussian, salt & pepper and speckle noise using average filter with minimum loss of image quality. Median filter is applicable for Salt and Pepper noise reduction. Order filter reduces the noise but reduce the quality of the image which is undesirable.

4. Conclusion

This paper points out different noise present in the digital image. The noise in the image may get added starting with lens of image capturing device up to digitization of an image. Gaussian noise, detector noise, salt and pepper noise are which are mostly get added to image. Gaussian noise and Salt and pepper are additive noise. The noise cleaning technique are classified into two type, linear noise cleaning and nonlinear noise cleaning. The image details is preserve in case of nonlinear whereas it get lost in linear noise cleaning. For reducing the Gaussian noise, speckle noise and Salt & pepper noise we can either use average filter or median filter. Median filter offers much better noise filtering.

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