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Performance Comparison of Various Filters for Removing Poisson Noise, Exponential Noise, Multiplicative Noise and Erlang Noise

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ABSTRACT
In Digital images there are many possibilities that images are prone to variety of noises. Therefore image de-noising is to be an essential part for image reconstruction process. Generally noise in image gets introduced during acquisition, transmission, reception and storage & retrieval processes. A detailed analysis of the various noises which corrupt an image is included in this paper. Removal of noises is done using various filters. To obtain significant results various filters have been proposed to remove these noises from images and finally which filter is most suitable to remove a particular noise is seen using various measurement parameters including Mean Square Error and Peak Signal to Noise Ratio.
Keywords: Poisson Noise, Multiplicative Noise, Erlang Noise, Exponential Noise, PSNR, MSE.

I. INTRODUCTION

When the digital images are processed using digital computers then removal or de-noising of noise is very essential [1]. In case of image noise is an unwanted signal which gives change in visibility of any image and occurs usually due to thermal or electrical signals such as from sensors or environmental conditions. The main problem at hand is removing the noise of an image while preserving its main features (edges, textures, colors, contrast, etc.) This has been regularly extensively investigated over the last two decades and numerous types of approaches have been developed. There are mainly two domain processes available for the restoring the image, first one is spatial domain and second one is frequency domain. In the spatial domain filtering action is done by operating on the pixel of the digital image directly for restoring the image. On the other hand filtering action is done by in frequency domain by mapping spatial domain into frequency domain of the image function by taking Fourier transform of the image function. After the filtering, in order to determine the restored image we have to re map the image into spatial domain by taking inverse Fourier transform. Noise may be generallyPoisson Noise, Multiplicative Noise,Erlang Noise and Exponential Noise. In this paper first image is taken and some noise is added to image to make it a noisy image and then noisy image is decomposed by filters. It becomes very important to de-noise the image before applying to different applications [2].The principle approach of image de-noising is filtering. Various filters are used to remove noise such as mid-point filters, median filters, mean filters etc. The image quality is measured by various performance parameters like the peak signal to noise ratio (PSNR) and mean square error (MSE) [3].

II. NOISE MODELS

The result of error in image acquisition process [4] that results in pixel values that do not reflect true intensities of the real picture is called noise. Using probability density functions we can define a set of noise models. The most occurring noises in digital images are Poisson noise, Exponential noise, Multiplicative noise, and Erlang noise or Gamma noise. Following, these noises are discussed at stretch.

2.1 Poisson Noise

Poisson noise or Shot noise is a type of electronic noise which can be modeled by a Poisson process. A Poisson model assumes that each pixel x of an image f (x) is drawn from a Poisson distribution of parameter λ = f (x) where f (0) is the clean intensity image to recover.

$$P\big(f(x = k)\big) = (\lambda^k e^{-\lambda})/k! \quad (1) \tag{1}$$

This model corresponds to a photon count [5], where λ is proportional to the number of photons that hits the receptor during the exposition time. This is useful to model medical imaging (confocal microscopy), TEP and SPECT tomography, and digital camera noises. The goal of de-noising is to retrieve the value of f0(x) =λ(x), the true image value, which corresponds to a clean image.

2.2 Exponential Noise
This noise is modeled on the exponential probability distribution which is a special case of erlang with b=1.

$$P(z) = \begin{cases} ae^{-z} & for z \geq 0; \\ 0 & for z < 0; \end{cases} \quad (2)$$

where a > 0.

2.3 Multiplicative Noise
Multiplicative noise refers to an unwanted random signal that gets multiplied into some relevant signal during capture, transmission, or other processing [7]. An important example is the speckle noise. Generalized model of the multiplicative noise is described by

$g(n, m) = f(n, m) * u(n, m) + k(n, m)$ (3)

Where, g(n, m) is the observed image, u(n, m) is the multiplicative component and k(n, m) is the additive component of the speckle noise [8]. Here n and m denote the axial and lateral indices of the image samples.

2.4 Erlang Noise
The PDF of Erlang noise [10] is given by

$$P(z) = \begin{cases} \dfrac{a^b z^{b-1}}{(b-1)!} e^{-az} & for \ z \geq 0 \\ 0 & for \ z < 0 \end{cases} \quad (4)$$

III. FILTERING TECHNIQUES
Removal of noise from the degraded image is done by filtering. There are two types of filtering techniques [13]. First one being spatial filtering and second one is frequency filtering. Spatial filtering is the filtering operations that are performed directly on the pixels of image. In Spatial Domain the filtering operation [14] is done by convolving the image pixels with the pixels of the mask. A mask is a small sub image, often of size 3×3 pixels. The mask size is varied according to the requirement. These include the following classes of filters
- Mean filters
- Order statistics filters
- Adaptive filters

3.1 Geometric Mean Filter
The working of a geometric mean filter is same as the arithmetic mean filter; the only difference is that instead of taking the arithmetic mean the geometric mean is taken. The restored image is given by the expression

$$f(x,y) = \left[\prod_{(s,t) \in S_{xy}} g(s,t) \right]^{\frac{1}{mn}} \quad (5)$$

3.2 Harmonic Mean Filter
In the harmonic mean method, the gray value of each pixel is replaced with the harmonic mean of gray values of the pixels in a surrounding region. The harmonic mean [16] is defined as

$$f(x,y) = \frac{mn}{\displaystyle\sum_{(s,t) \in S_{xy}} \frac{1}{g(s,t)}} \quad (6)$$

3.3 Contra Harmonic Mean Filter
The contra harmonic mean filter operation is given by the expression

$$f(x,y) = \frac{\displaystyle\sum_{(s,t) \in S_{xy}} g(s,t)^{Q+1}}{\displaystyle\sum_{(s,t) \in S_{xy}} g(s,t)^{Q}} \quad (7)$$

Where Q is called the order of the filter. This filter is well suited for reducing or virtually eliminating the effects of salt-and-pepper noise.

3.4 Median Filter
Order-statistics filters are based on ordering the pixels contained in the mask. Median filter comes under this class of filters. Median filter replaces the value of a pixel with the median value of the gray levels within the filter window [17] or mask. Median filters are very effective for impulse noise.

$$f(x,y) = \underset{(s,t) \in S_{xy}}{median} \{g(s,t)\} \quad (8)$$

3.5 Midpoint filter
This filter computes the midpoint between the maximum and minimum values in the area encompassed by the filter. This filter works best for randomly distributed noise like Gaussian noise.

$$f(x,y) = \frac{1}{2} \left[\underset{(s,t) \in S_{xy}}{max} \{g(s,t)\} + \underset{(s,t) \in S_{xy}}{min} \{g(s,t)\} \right] \quad (9)$$

IV. PERFORMANCE MEASUREMENT PARAMETERS
Consider an image of dimensions M and N. If f(x, y) is the original image and g(x, y) is the distorted image then the various measurement parameters are described as follows.

4.1 Mean Square Error (MSE)
The MSE [19] is cumulative squared error between the compressed and the original image. It is calculated using

$$MSE = \frac{1}{MN} \sum_{0}^{M-1} \sum_{0}^{N-1} ||f(x,y) - g(x,y)|| \quad (10)$$

4.2 Peak Signal to Noise Ratio (PSNR)
The PSNR is used to determine the ratio between the maximum power of a signal and power of corrupting noise. The formula of PSNR is given as

$$PSNR = 10\, log_{10}\left[\frac{M*N}{MSE}\right] \qquad (11)$$

4.3 Average Difference (AD)
The average difference is given by the formula
AD=$|f(x,y) - g(x,y)|$ (12)

4.4 Maximum Difference (MD)
The maximum difference is given by the formula
MD= $\max|f(x,y) - g(x,y)|$ (13)

4.5 Normalized Absolute Error (NAE)
The normalized error is given by

$$y = NAE = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N}(f(x,y)*g(x,y))}{\sum_{x=1}^{M}\sum_{y=1}^{N}(f(x,y))^2} \qquad (14)$$

4.6 Structural Content (SC)
SC is correlation based measure and measures the similarity between two images. It is given by the equation

$$SC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(y(i,j))^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j))^2} (15)$$

V. SIMULATION RESULT AND ANALYSIS

Simulation has been run on MATLAB using gray scale image 'lena.bmp' of size 512 x 512 as a test image shown in Fig 1

Fig. 1. Test Image Lena

For each and every noise all seven filters are applied in sequence and parameters are distinguished which are given below in the table. Table 1 shows the different measurement parameters after applying all the filters for Poisson noise.

Table.1   POISSON NOISE

FILTER	MSE	PSNR	AD	MD	NAE	SC
Arithmetic Filter	114.31	27.549	0.413	112	0.062	1.0073
Geometric Filter	24.46	34.244	3.102	182	0.031	0.991
Harmonic Filter	31.15	33.196	3.889	182	0.039	1.0017
Contra-Harmonic Filter	252.15	24.11	98.72	252	0.996	159.37
Median Filter	19.79	35.16	2.56	135	0.0259	0.9983
Max and Min Filter	79.63	29.11	10.26	182	0.103	1.0192
Mid-Point Filter	16.2437	36.02	2.1378	89	0.0216	0.9975

Table 2 shows the different measurement parameters after applying all the filters for Multiplicative noise.

Table.2 MULTIPLICATIVE NOISE

FILTER	MSE	PSNR	AD	MD	NAE	SC
Arithmetic Filter	32.4189	33.0228	3.946	111	0.0398	0.9975
Geometric Filter	51.9361	30.9761	5.325	182	0.0538	0.9987
Harmonic Filter	68.6100	29.7669	6.994	182	0.0706	1.0006
Contra-Harmonic Filter	252.150	24.1142	98.697	252	0.9965	155.07
Median Filter	50.9206	31.0619	5.161	135	0.0521	0.9983
Max and Min Filter	80.2308	29.0874	10.334	182	0.1043	1.0192
Mid-Point Filter	16.5379	35.9460	2.17731	89	0.0219	0.9975

Table 3 shows the different measurement parameters after applying all the filters for Exponential noise.

Table.3   EXPONENTIAL NOISE

FILTER	MSE	PSNR	AD	MD	NAE	SC
Arithmetic Filter	7.9138	39.1470	0.936	102	0.0095	0.9989
Geometric Filter	5.8860	40.4326	0.701	112	0.0071	0.9975
Harmonic Filter	9.3786	38.4094	1.143	157	0.0115	0.9980
Contra-Harmonic Filter	251.964	24.1174	98.501	252	0.9945	125.28
Median Filter	4.3344	41.7615	0.588	135	0.0059	0.9970
Max and Min Filter	70.7486	29.6336	9.17116	182	0.0926	1.0149
Mid-Point Filter	15.9580	36.1010	2.1084	89	0.0213	0.9975

Table 4 shows the different measurement parameters after applying all the filters for Erlang noise.

Table.4   ERLANG NOISE

FILTER	MSE	PSNR	AD	MD	NAE	SC
Arithmetic Filter	1.4751	46.4425	0.173	81	0.0018	0.9997
Geometric Filter	0.6050	50.3136	0.0062	97	0.000063402	0.9990
Harmonic Filter	1.7048	45.8142	0.195	131	0.0020	0.9981
Contra-Harmonic Filter	251.671	24.1225	98.198	252	0.9914	106.41
Median Filter	0.4291	51.8054	0.0052	135	0.00053111	0.9987
Max and Min Filter	42.9052	31.8057	5.61172	175	0.0567	1.0041

FILTER	MSE	PSNR	AD	MD	NAE	SC
Mid-Point Filter	15.9580	36.1010	2.1084	89	0.0213	0.9975

VI. CONCLUSION

On seeing the parameters shown in the above tables we can conclude that which filter will be best for removing respective noise. This conclusion is stated below in the Table 5.

Table.5 FILTERS TO BE CHOSEN FOR DIFFERENTNOISES

NOISES	FILTERS
Poisson Noise	Mid-Point Filter
Erlang Noise	Geometric Mean Filter
Multiplicative noise	Mid-Point Filter
Exponential Noise	Median Filter

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