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Study of Various Image Noises and Their Behavior

Sumit Kushwaha[1*], Dr. Rabindra Kumar Singh[2]
[1,2]Electronics Engineering Department/Kamla Nehru Institute of Technology, Sultanpur/India - 228118 and

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***Abstract*— Noises in image is a random variation of color and brightness information produced by the sensor and circuitary of a scanner, or digital camera, or transmission of images. Noise can degrade the visual quality of the image. Due to this, we lost so many information from the image. Image Denoising means to restore the noisy image in original form and extract the maximum information as much as possible. In this paper, we studied the various types of noises in the image, how its behavior, with some parameters, with the help of PDF functions using MATLAB.**

Keywords- Speckle Noise, Gaussian Noise, Uniform Noise, Exponential Noise, Gamma Noise, Rayleigh Noise, Impulsive Noise.

I. Introduction

Image processing is a field that continuous to grow, with new applications being developed at an ever increasing pace. It is a fascinating and exciting area to be involved in today with application areas ranging from the entertainment industry to the space program. Visual information transmitted in the form of digital images has become a major method of communication for the 21st century. Image processing is any form of signal processing for which the input is an image, such as photographs or frames of video and output of image processing can be either an image or set of characteristics or parameters related to the image. It is well known that while receiving the input image some abbreviation get introduced along with it and hence a noisy image [3]. Noises in image are a random variation of color and brightness information produced by the sensor and circuitry of a scanner, or digital camera, or transmission of images, or thermal energy of heat inside the image sensors. The image Denoising naturally corrupted by noise is a classical problem in the field of signal or image processing.

II. Types of Image Noises

The most common noises arise in the image are:

A. *Amplifier Noise (Gaussian Noise, or Normal Noise):*

Gaussian noise is statistical noise having a probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution [4]. This noise is independent of intensity of the image in which it is applied to. The PDF P(z) of Gaussian random variable z is given by:

$$P(z) = \frac{1}{\sigma\sqrt{(2\pi)}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$$, where z is grey level intensity, μ is the mean value (mean value of the elements in z is a row vector containing the mean value of each column. If z = [0, 1, 2; 3, 4, 5], then mean (z, 1) is [1.5, 2.5, 3.5] and mean (z, 2) is [1, 4].) and σ standard deviation (standard deviation is a measure of the amount of spread around the central peak. At low standard deviations, the central bins are concentrated near the mean and the peak is very tall and sharp. At high deviations, the peak is lower and the values are more evenly distributed to outlying bins.).

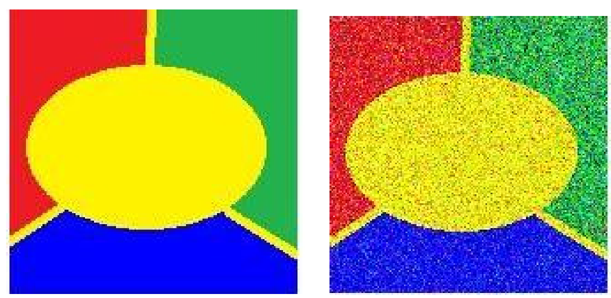

Figure: 1: Original Test Image and Gaussian noise zero mean 0.06 variance

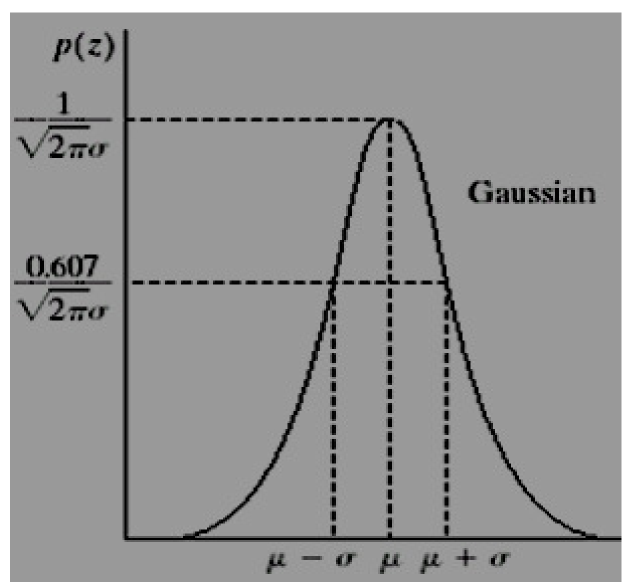

Figure 2: PDF Curve of Gaussian Noise [2].

```
%% Gaussian_Noise_addition_code:
I = imread('test.jpg');
J = imnoise(I,'gaussian',0,0.06);
figure, imshow(I)
figure, imshow(J)
```

B. *Salt-and-pepper Noise (Impulse Noise, or Spike Noise):*

An image containing salt and pepper noise will have dark pixels in bright regions and bright pixels in dark regions [5]. Salt and pepper noise is usually caused by faulty memory locations, malfunctioning pixel elements in the camera sensors, or there can be timing errors in the process of digitization [2]. The PDF P(z) of salt and pepper noise random variable z is given by:

$$P(z)=\begin{Bmatrix} P_a, & for\ z=a \\ P_b, & for\ z=b \\ 0, & otherwise \end{Bmatrix}$$

, where z is a grey level intensity, a and b are two points in grey level intensity of probabilities P_a and P_b respectively.

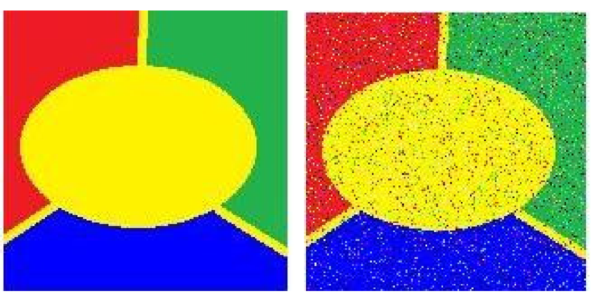

Figure: 3: Original Test Image and Salt and pepper noise with 0.09 noise density

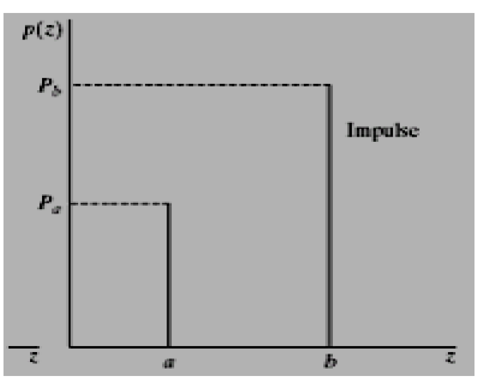

Figure 4: PDF Curve of Salt and pepper noise [2].

```
%%Salt_and_pepper_Noise_addition_code
I = imread('test.jpg');
J = imnoise(I,'salt & pepper',.09);
figure, imshow(I)
figure, imshow(J)
```

For Salt and pepper noise, the default value of the noise density is 0.05.

C. *Shot Noise (Poisson Noise, or Photon 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 [7]. 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 [6]. If I (input image) is double precision, then input pixel values are interpreted as means of Poisson distributions scaled up by 1e12. For example, if an input pixel has the value 5.5e-12, then the corresponding output pixel will be generated from a Poisson distribution with mean of 5.5 and then scaled back down by 1e12. If I is single precision, the scale factor used is 1e6. If I is uint8 or uint16, then input pixel values are used directly without scaling. For example, if a pixel in a uint8 input has the value 10, then the corresponding output pixel will be generated from a Poisson distribution with mean 10 [8]. The PDF of Poisson distribution noise is given by:

$$P(z)=\frac{\mu^z e^{-\mu}}{z!}$$

, where z is grey level intensity, μ is mean value(sometimes μ is replaced by λ).

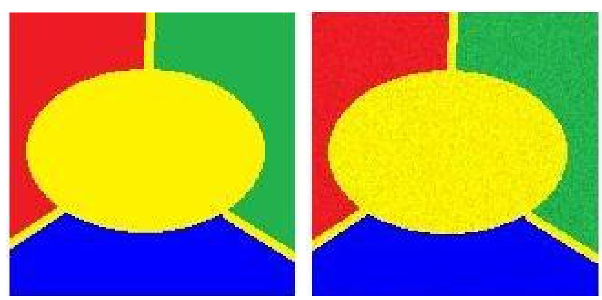

Figure: 5: Original Test Image and Poisson Noise

```
%% Poisson_Noise_addition_code
I = imread('test.jpg');
J = imnoise(I,'poisson');
figure, imshow(I)
figure, imshow(J)
```

D. Multiplicative Noise (Speckle Noise) :

The multiplicative noise can be shown by random value multiplications with image and added to the pixel values of the image and can be expressed as:

$J = I + n*I$, where, J is the speckle noise distribution image, I is the input image and *n* is the uniform noise image by mean value, μ = 0 (zero) and variance, σ. This noise deteriorates the quality of active radar and Synthetic aperture radar (SAR) images. This noise is originated because of 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. Mean filters are good for Gaussian noise and uniform noise [1].

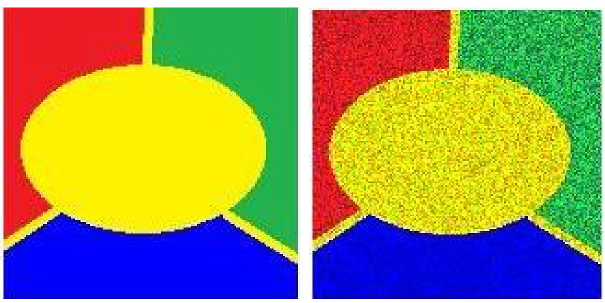

Figure: 6: Original Test Image and Speckle noise with 0.08 noise variance

```
-------------------------------------------------------
%% Speckle_Noise_addition_code
 I = imread('test.jpg');
J = imnoise(I,'speckle',0.08);
figure, imshow(I)
figure, imshow(J)
-------------------------------------------------------
```

E. Quantization Noise (Uniform Noise):

Quantization noise caused by quantizing the pixels of a sensed image to a number of discrete levels [9]. Quantization noise is inherent in the amplitude quantization process and occurs in the ADC. The noise is additive and independent of the signal when the number of levels L >= 16. This is quivalent to B >= 4 bits. If ADC is adjusted so that 0 corresponds to the minimum electrical value and $2^B - 1$ corresponds to the maximum electrical value then, Quantization Noise:

$SNR_{dB} = 6*B + 11$ (dB). For B >= 8 bits, this means a SNR >= 59 dB. Quantization noise can usually be ignored as the total SNR of a complete system is typically dominated by the smallest SNR [10]. The PDF of quantization noise is given by:

$P(z) = \begin{cases} \frac{1}{(b-a)}, & if\ a \le z \le b \\ 0, & otherwise \end{cases}$, where z is a grey level intensity, a and b are two points in grey level intensity of probability 1/(b-a), μ is the mean value and σ is the noise variance in the image.

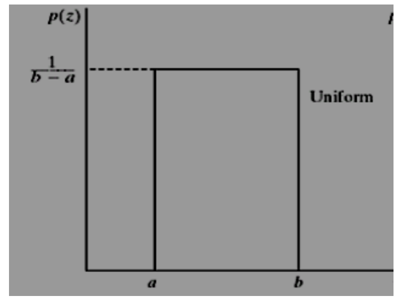

Figure 7: PDF Curve of Quantization Noise [2].

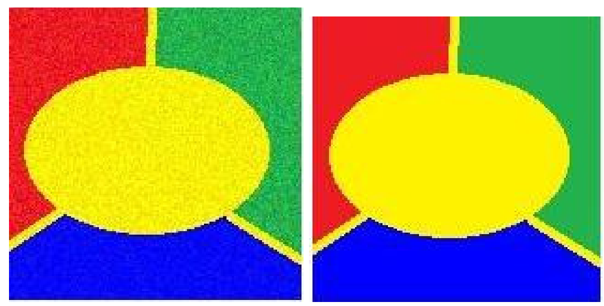

Figure: 8: Original Test Image and Quantization noise with 60 scaling

imnoise () does not support Quantization noise (Uniform Noise). Here, scale is the maximum magnitude you want to use.

```
-------------------------------------------------------
%% Quantization_Noise_addition_code
 I = imread('test.jpg');
I=double(I);
a=-30;
b= 30;
scale=b-a;
J = I+a+scale*rand(size(I));
o=uint8(I);
figure, imshow(o)
figure, imshow(J./255)
-------------------------------------------------------
```

F. Rayleigh Noise:

Radar range and velocity images typically contains noise that can be modeled by the Rayleigh distribution [2]. The PDF of the Rayleigh distribution noise is given by:

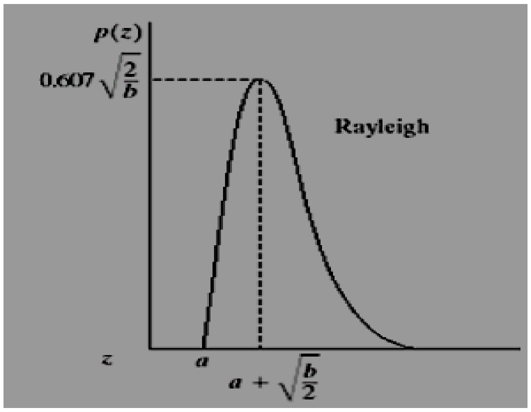

Figure 9: PDF Curve of Rayleigh distribution Noise [2].

$P(z)=\frac{2}{b} * (z-a) * e^{-\frac{(z-a)^2}{b}}$, for z ≥ a and 0 for z < a.
where z is a grey level intensity, a and b are two points in grey level intensity, mean value, $\mu = a + \sqrt{\pi b/4}$ and noise variance, $\sigma = \sqrt{\frac{b(4-\mu)}{4}}$ in the image.

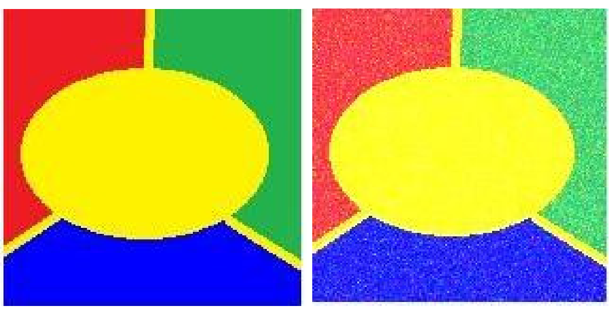

Figure: 10: Original Test Image and Rayleigh noise

```
-------------------------------------
%% Rayleigh_Noise_addition_code
 I = imread('test.jpg');
I=double(I);
a= 10;
b= 50;
J = I+a+(-b*log(1-rand(size(I)))).^0.9;
o=uint8(I);
figure, imshow(o)
figure, imshow(J./255)
-----------------------------------
```

G. Gamma Noise (Erlang Noise):

Gamma noise can be obtained by the low-pass filtering of laser based images [2]. The PDF of the Gamma distribution noise is given by:

$P(z)=\begin{Bmatrix} \frac{a^b z^{(b-1)}}{(b-1)!} * e^{-az}, & for\ z \geq 0 \\ 0, & for\ z < 0 \end{Bmatrix}$, where z is a grey level intensity, a and b are two points in grey level intensity, mean value, $\mu = \frac{b}{a}$ and noise variance, $\sigma = \sqrt{\frac{b}{a^2}}$ in the image.

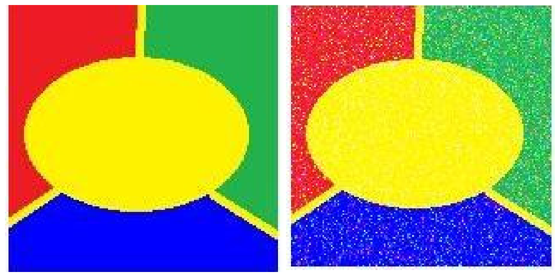

Figure: 11: Original Test Image and Rayleigh noise

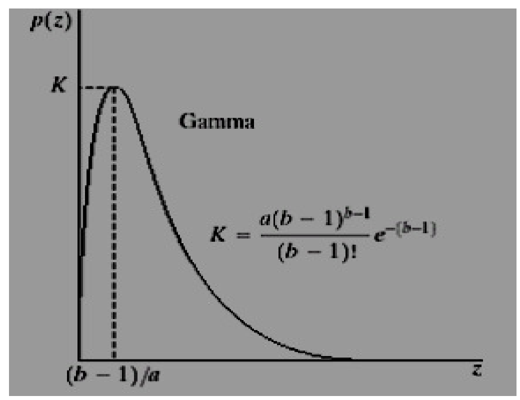

Figure 12: PDF Curve of Gamma distribution Noise [2].

```
------------------------------
%% Gamma_Noise_addition_code
I = imread('test.jpg');
I=double(I);
a= 0.1;
b= 10;
sigma=sqrt(b/a^2);
J=I+sigma*gamrnd(a,b,[size(I)])
o=uint8(I);
figure, imshow(o)
figure, imshow(J./255)
--------------------------------
```


H. Film Grain Noise:

The grain of photographic film is a signal-dependent noise, with similar statistical distribution to shot noise [11]. If film grains are uniformly distributed (equal number per area), and if each grain has an equal and independent probability of developing to a dark silver grain after absorbing photons, then the number of such dark grains in an area will be random with a binomial distribution. In areas where the probability is low, this distribution will be close to the classic Poisson distribution of shot noise. A simple Gaussian distribution is often used as an adequately accurate model [9].

I. Non- Isotropic Noise:

Some noise sources show up with a significant orientation in images. For example, image sensors are sometimes subject to row noise or column noise [12].

Figure 13: Non- Isotropic Noise with column noise [13].

J. Exponential Noise (Laplace noise):

A variable z has a Laplace distribution (μ, b) if its PDF is [14]:

$$P(z)=\frac{1}{2b}\begin{cases} \exp\left(-\frac{\mu-z}{b}\right), & if\ z < \mu \\ \exp\left(-\frac{z-\mu}{b}\right), & if\ z \geq \mu \end{cases}$$

, where z is a grey level intensity, b is a point in grey level intensity (b > 0, sometimes b is referred to as the diversity, a scale parameter), mean value, μ in the image.

III. CONCLUSIONS

Image restoration of a noisy image is necessary task in digital image processing. In this paper, we have studied various types of image noise that creep in image during acquisition or transmission. We also studied how these noises generate in MATLAB and addition of it into image and understand image noise behavior with the help of PDF function.

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We would like to thanks MATLAB® Central and others to understand these types of image noises.

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AUTHORS PROFILE

Sumit Kushwaha is working as Research cumTeaching Fellow in EL Department, Kamla Nehru Institute of Technology, Sultanpur.

Dr. Rabindra Kumar Singh is working as Associate Professor in EL Department, Kamla Nehru Institute of Technology, Sultanpur.

