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Noise Models in Digital Image Processing

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Abstract: Digital images carry large amount of information and play important role in every aspect of life. So, images are required to be in accurate form. However, during image acquisition, coding, transmission and processing, images are getting degraded by noise. noise interference changes true pixel value and distorts most of the part of image. Hence noise removal is important and it requires prior knowledge of type of noise, its effects and causes. So, this paper gives an over view of various types of noise.

Keywords: Noise models, PDF, mean, standard deviation

I. INTRODUCTION

Digital image carries large amount of information and it is medium of communication between people. It plays vital role in every aspect of life. So, these images are required to be in accurate form so that they can be used effectively. However, digital images are often degrading due to degrading process which involves degradation function and noise [1]. Fig. 1 shows model of image degradation process.

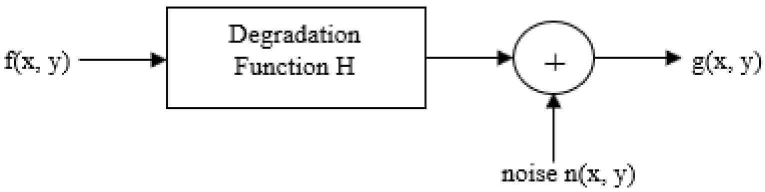

Fig. 1 Image degradation process model

As shown, a degradation function H along with additive noise term n(x, y) operates on input image f(x, y) to produce degraded image g(x, y). If H is linear, position invariant process, then in spatial domain, degraded image is given by

$$g(x, y) = h(x, y) * f(x, y) + n(x, y) \quad (1)$$

where h(x, y) is spatial representation of degradation function and * represents convolution operation. If only degradation present in an image is noise then equation 1 becomes

$$g(x, y) = f(x, y) + n(x, y) \quad (2)$$

Noise is unwanted and random variation in brightness or color information that produces different pixel value instead of true pixel value [2, 3]. Noise distorts most of the part of the image. Noise may get introduced during image acquisition, coding, transmission and processing steps [4]. Noise may get added due to environmental conditions such as temperature, light level, humidity, dust particles, lightening, and weather conditions. Imperfections in image capturing devices such as malfunctioning pixels in camera sensors, poor quality and misaligned lenses, faulty memory locations etc. and transmission of image through noisy channel can also induce noise.

The interference of noise results in undesired results such as blurring, artifacts, unrealistic edges, unseen lines [4]. It can also affect performance of sub sequent image processing operations such as edge detection, image segmentation and classification etc. [5]. Hence it is essential to remove these undesired results.

Image restoration techniques attempt to recover an image that has been degraded by using a priori knowledge of degradation phenomenon and or noise. Restoration techniques are oriented towards modelling degradation and applying

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suitable process to recover original image by using a criterion of goodness that will yield an optimal estimate of the desired result.

As equation 2 suggests that by subtracting noise term from g(x, y), original image f(x, y) could be recovered. But noise terms are often unknown so subtracting them is not a realistic option. Hence before restoration prior knowledge of noise model and its characteristics is essential. Therefore, in this paper review of some important noise models is presented in section II and conclusion is drawn in section III.

II. NOISE MODELS

We assume that noise is independent of spatial co-ordinates and it is uncorrelated with respect to image itself to avoid the complexities of spatially dependent and correlated noise. Based on these assumptions, statistical behaviour of the intensity values of noise component may be considered random variable characterized by a probability distribution function (PDF). The following are some important PDFs found in digital image processing applications.

1. Gaussian noise

Gaussian noise arises in amplifier or detectors, so it is also known as amplifier noise and electronic noise. Natural resources such as thermal vibrations of atoms, discrete nature of radiation of warm objects are causes of Gaussian noise [4]. It is evenly distributed and every pixel in degraded image is sum of true value and random Gaussian distributed noise value [2]. The PDF of Gaussian noise is given by,

$$p(g) = \frac{1}{\sqrt{2\pi}\ \sigma} e^{\frac{-(g-\bar{g})^2}{2\sigma^2}}$$

where g represents intensity, $\bar{g}$ is mean value of g, σ is standard deviation. A plot of this function is shown in Fig. 2. It shows that approximately 70% noisy pixels are in the image range ($\bar{g}$ - σ) and ($\bar{g}$ + σ).

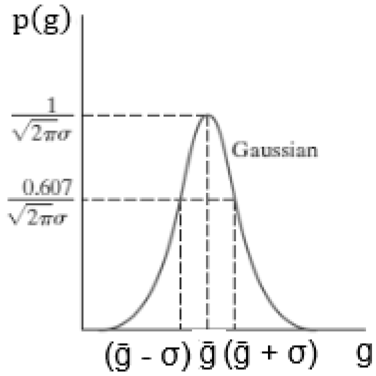

Fig. 2 PDF of Gaussian noise

2. Rayleigh noise

Rayleigh noise presents in radar range and velocity images [2, 4]. It is not symmetric. The PDF of Rayleigh noise is given by,

$$p(g) = \frac{2}{b}(g-a)e^{\frac{-(g-a)^2}{b}} \qquad \text{for } g \geq a$$
$$= 0 \qquad \text{for } g < a$$

The mean and variance of this density are given by

$$\bar{g} = a + \sqrt{\frac{\pi b}{4}}$$
$$\sigma^2 = \frac{b(4-\pi)}{4}$$

Fig. 3 shows PDF of Rayleigh noise.

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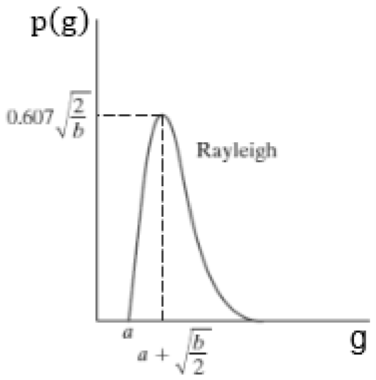

Fig. 3 PDF of Rayleigh noise

3. Erlang noise

Erlang noise is generally seen in laser based images and obeys Gamma distribution. So, it is also known as Gamma noise. The PDF of Erlang noise is given by

$$p(g) = \begin{cases} \dfrac{a^b g^{b-1}}{(b-1)!} e^{-ag} & g \geq 0 \\ = 0 & g < 0 \end{cases}$$

where parameters are such that a > b, b is a positive integer. The mean and variance of g are

$$\bar{g} = \frac{b}{a}$$

and

$$\sigma^2 = \frac{b}{a^2}$$

Fig. 4 shows plot of this density

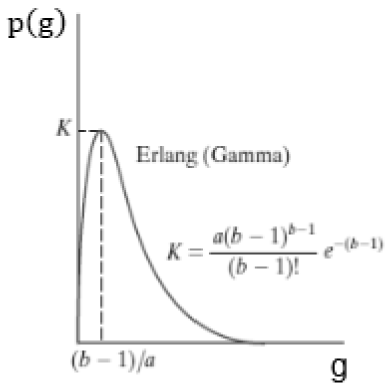

Fig. 4 PDF of Erlang noise

4. Uniform or quantization noise

It is inherently present in amplitude quantization process [4]. It is caused by quantizing the pixels of a sensed image to a number of discrete levels. It obeys uniform distribution. Its PDF is given by

$$p(g) = \begin{cases} \dfrac{1}{b-a} & \text{for } a \leq g \leq b \\ = 0 & \text{otherwise} \end{cases}$$

The mean of this density function is given by

$$\bar{g} = \frac{a+b}{2}$$

and its variance is given by

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$$\sigma^2 = \frac{(b-a)^2}{12}$$

Fig. 5 shows its PDF.

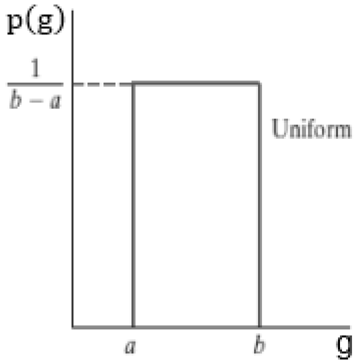

Fig. 5 PDF of Uniform noise

5. Impulse or Salt and Pepper noise
The PDF of bipolar impulse noise is given by

$$p(g) = \begin{cases} Pa & \text{for } g = a \\ Pb & \text{for } g = b \\ 0 & \text{Otherwise} \end{cases}$$

If b > a, intensity b will appear as a light dot in the image. Conversely, intensity a will appear as a dark dot. If either Pa or Pb is zero, the impulse noise is called as unipolar, otherwise called as bipolar noise [1]. Fig. 6 shows PDF of bipolar impulse noise.
Usually, impulse corruption is large compared with image signal, impulse noise is generally digitized as extreme or saturated values in an image. Thus, usually assumption is that a and b equal to minimum and maximum allowed values in the digitized image. As a result, negative impulse (minimum allowed value) appears as black (pepper) points and positive impulse (maximum allowed value) appears as white (salt) points in the image. So impulse noise is also called as salt and pepper noise [1]. Data drop out and spike noise are also the terms used for impulse noise. causes of impulse noise are malfunctioning pixels in camera sensors, faulty memory locations, transmission through noisy channel.

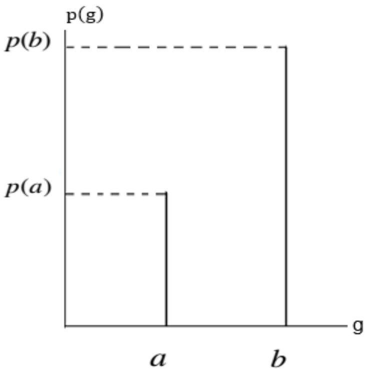

Fig. 6 PDF of Impulse noise

6. Brownian noise/ Fractal noise
In Brownian noise, power spectral density is proportional to square of frequency over an octave [4]. Brownian noise is caused by Brownian motion which is seen due to random movement of suspended particles in fluid. Brownian noise is known by many names such as coloured noise, pink noise, flicker noise.

7. Photon noise/ Poisson noise
Photon noise appears due to statistical nature of electromagnetic waves like x-rays, visible light and gamma rays [4]. The x-ray and gamma ray sources emittes number of photos per unit time. In medical x-ray and gamma ray imaging systems,

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these rays are injected in patient's body from the source. These sources are having random fluctuations of photons. So, if number of photons sensed by sensor is in sufficient to provide detectable statistical information, resulting image has spatial and temporal randomness [2]. This noise obeys Poisson distribution.

III. CONCLUSION

Digital images are often getting degraded due to noise interference which results in undesired results and also affects performance of subsequent image processing operations. Hence removal of these undesired results is essential. Image restoration techniques attempt to recover image by using priori knowledge of noise. Therefore, this paper in detail reviews different types of noise, their causes and density functions are presented.

BIOGRAPHY

Vinayak C. Sakhare has completed his B. E. Electronics Engineering in 2004 and M. E. Electronics Engineering degree in 2014 from Textile & Engineering Institute. His areas of interest are Image Processing, Embedded Systems. Currently he is working as Assistant Professor at Textile and Engineering Institute.

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