3.4 NOISE MODELS (NOISE DISTRIBUTION)

The principal noise sources in the digital image arise during image acquisition or digitization or transmission. The performance of imaging sensors is affected by a variety of factors such as environmental conditions during image acquisition and by the quality of the sensing elements.

Assuming the noise is independent of spatial coordinates and it is uncorrelated with respect to the image itself.

Noise in digital images is an unwanted disturbance that affects image quality. It may occur during image acquisition, transmission, storage, or processing. Different noise models are used to represent different types of disturbances mathematically.

Types of Noise Models

Gaussian Noise

Gaussian noise is the most common noise model in image processing.
It is also called **Normal Noise** because its intensity distribution follows the Gaussian (normal) distribution.

Characteristics

- Caused by electronic circuit noise and sensor noise.
- Affects almost every pixel.
- Mean value is usually zero.
- **Gaussian Noise:** It occurs due to electronic circuit noise, sensor noise due to poor illumination and/or high temperature

  The PDF of Gaussian random variable, z, is given by

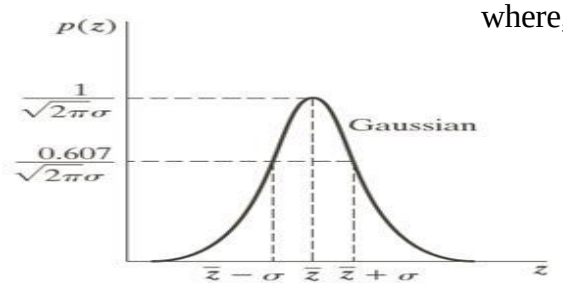
Applications

- Camera sensor noise
- Thermal noise in electronics

Appearance

Image looks grainy and blurred.

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



where, z represents intensity

$\bar{z}$ is the mean (average) valueof z

σ is the standard deviation

The PDF of Gaussian random variable, z, is given by

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

70% of its values will be in the range $[(\mu-\sigma),(\mu+\sigma)]$

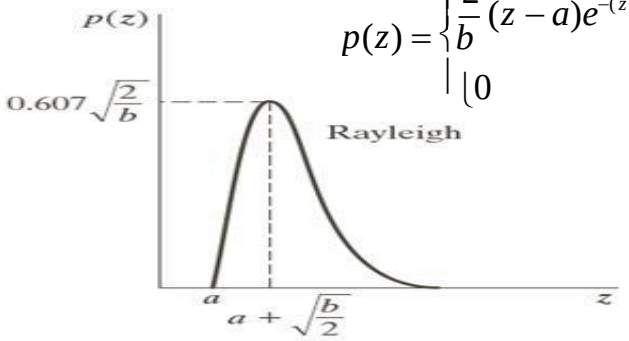
95% of its values will be in the range $[(\mu-2\sigma),(\mu+2\sigma)]$

1. Rayleigh Noise

It occurs due to Range imaging and is used for approximating skewed histograms.

The PDF of Rayleigh noise is given by

$$p(z) = \begin{cases} \frac{2}{b}(z-a)e^{-(z-a)^2/b} & \text{for } z \geq a \\ 0 & \text{for } z < a \end{cases}$$



The mean and variance of this density are given by

$$\bar{z} = a + \sqrt{\pi b/4}$$

$$\sigma^2 = \frac{b(4-\pi)}{4}$$

2. Erlang (Gamma) Noise

It occurs due to laser imaging

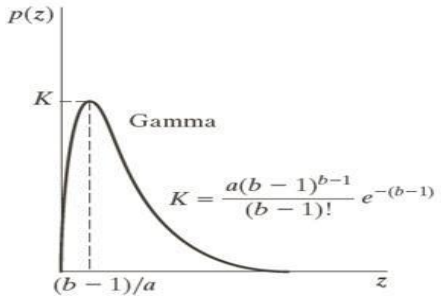
The PDF of Erlang noise is given by

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

The mean and variance of this density are given by

$$\bar{z} = b/a$$

$$\sigma^2 = b/a^2$$



Where a > 0, b is a positive integer and "!" indicates factorial.

3. Exponential Noise

It occurs due to laser imaging

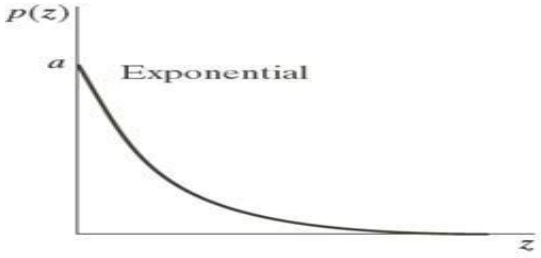
The PDF of exponential noise is given b y

$$p(z) = \begin{cases} ae^{-az} & \text{for } z \geq 0 \\ 0 & \text{for } z < a \end{cases}$$

The mean and variance of this density ar e given by

$$\bar{z} = 1/a$$

$$\sigma^2 = 1/a^2$$



4. Uniform Noise

It is a Least descriptive and basis for numerous random number generators

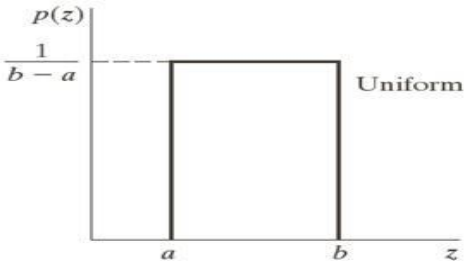
The PDF of uniform noise is given by

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

The mean and variance of this density are given by

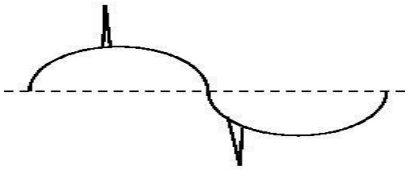
$$\bar{z} = (a+b)/2$$

$$\sigma^2 = (b-a)^2/12$$



5. Impulse (Salt-and-Pepper) Noise

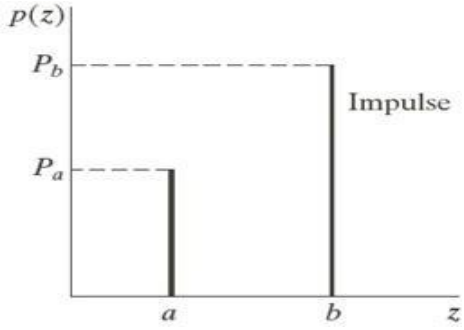
It occurs due to quick transients such as faulty switching



Impulse Noise

The PDF of (bipolar) impulse noise is given by

$$p(z) = \begin{cases} P_a & \text{for } z = a \\ P_b & \text{for } z = b \\ 0 & \text{otherwise} \end{cases}$$



If b > a, gray level b will appear as a light dot and level a will appear like a dark dot.
If either P_a or P_b is zero, then the impulse noise is called Unipolar
When a = minimum gary level value = 0, denotes negative impulse appearing black (pepper) points in an image and when b = maximum gray level value = 255, denotes positive impulse appearing white (salt) noise, hence it is also called **as salt and pepper noise or shot and spike noise**

6. Periodic Noise

Periodic noise in an image arises typically from electrical or electromechanical interference during image acquisition.It is a type of spatially dependent noise

Periodic noise can be reduced significantly via frequency domain filtering