Principle Sources of Noise

- Image Acquisition
  - Image sensors may be affected by Environmental conditions (light levels etc)
  - Quality of Sensing Elements (can be affected by e.g. temperature)
- Image Transmission
  - Interference in the channel during transmission e.g. lightening and atmospheric disturbances

Noise Model Assumptions

- Independent of Spatial Coordinates
- Uncorrelated with the image i.e. no correlation between Pixel Values and the Noise Component

White Noise

- When the Fourier Spectrum of noise is constant the noise is called White Noise
- The terminology comes from the fact that the white light contains nearly all frequencies in the visible spectrum in equal proportions
- The Fourier Spectrum of a function containing all frequencies in equal proportions is a constant

Noise Models: Gaussian Noise

Spatial noise descriptor based on the statistical behavior of the gray-level values ⇨ consider the gray-level values as random variables characterized by a probability density function (PDF)

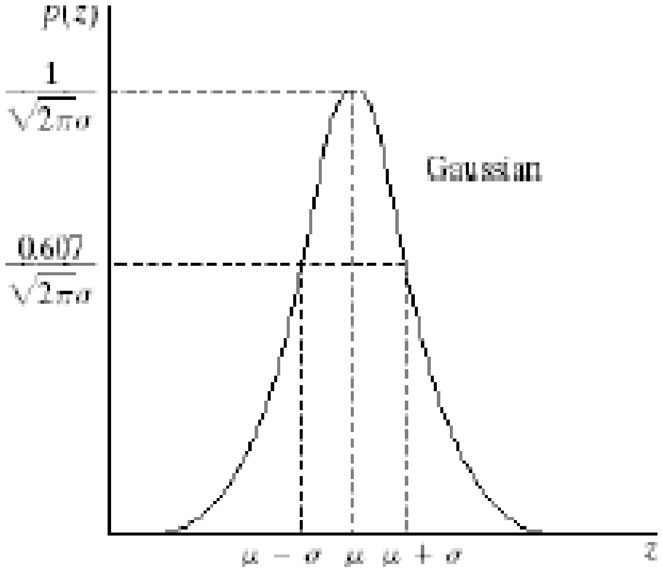
- Gaussian noise (also called "normal noise model")

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

z: gray level

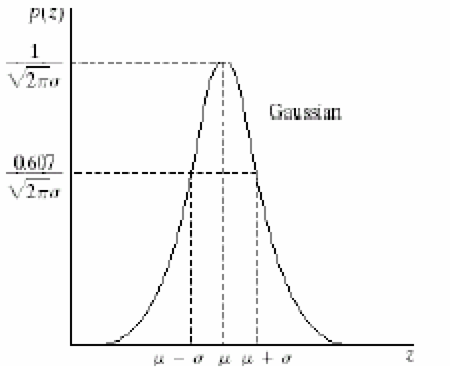
μ: mean of random variable z

σ^2: variance of z



Noise Models: Gaussian Noise

- Approximately 70% of its value will be in the range [(μ-σ), (μ+σ)] and about 95% within range [(μ-2σ), (μ+2σ)]
- Gaussian Noise is used as approximation in cases such as Imaging Sensors operating at low light levels

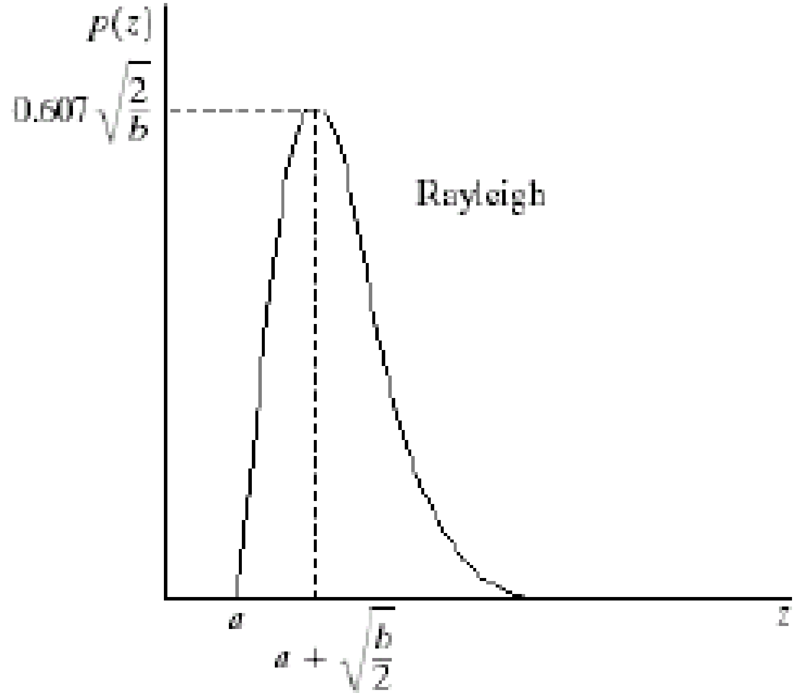


Noise Models: Rayleigh Noise

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

$$\text{mean}: \mu = a + \sqrt{\frac{\pi b}{4}}$$

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



Rayleigh density can be used to approximate skewed histograms

Rayleigh Noise arises in Range Imaging

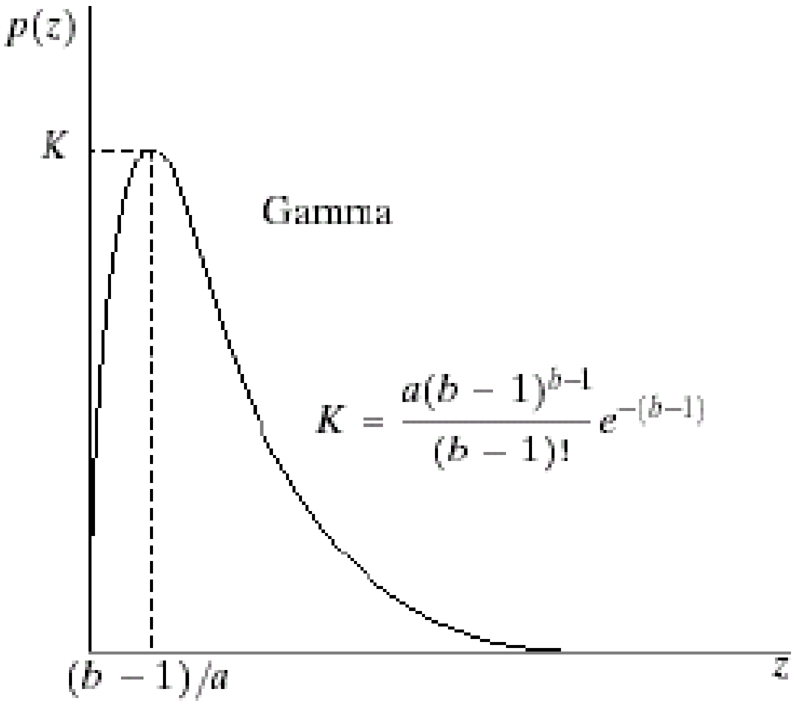
Noise Models: Erlang (Gamma) Noise

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

$$a > 0, b \in I+$$

$$\text{mean}: \mu = \frac{b}{a}$$

$$\text{variance}: \sigma^2 = \frac{b}{a^2}$$



Rayleigh Noise arises in Laser Imaging

Noise Models: Exponential Noise

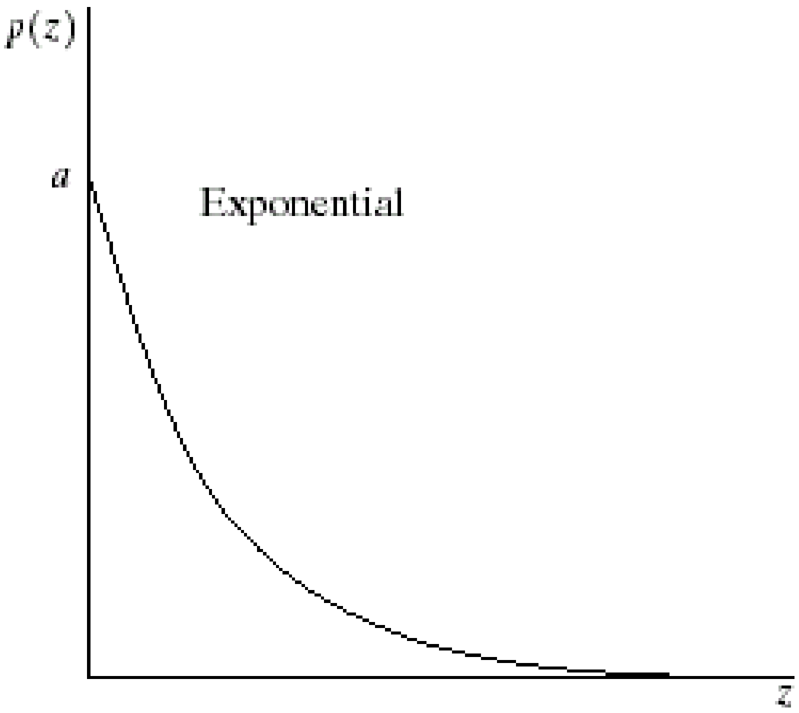
Special case of the Erlang PDF (b=1)

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

Where $a > 0,$

$$\text{mean}: \mu = \frac{1}{a}$$

$$\text{variance}: \sigma^2 = \frac{1}{a^2}$$

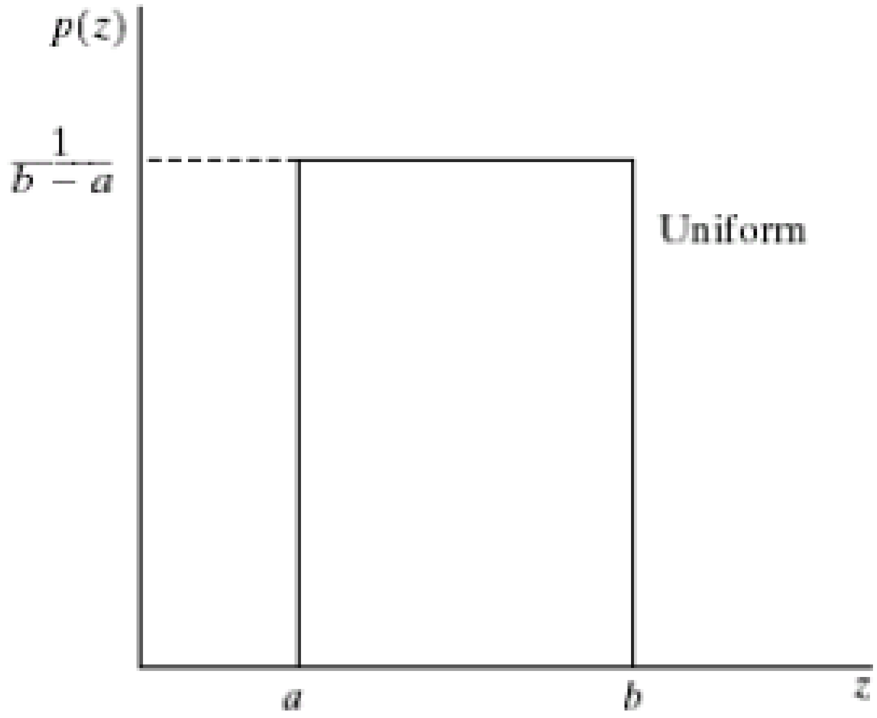


Noise Models: Uniform Noise

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

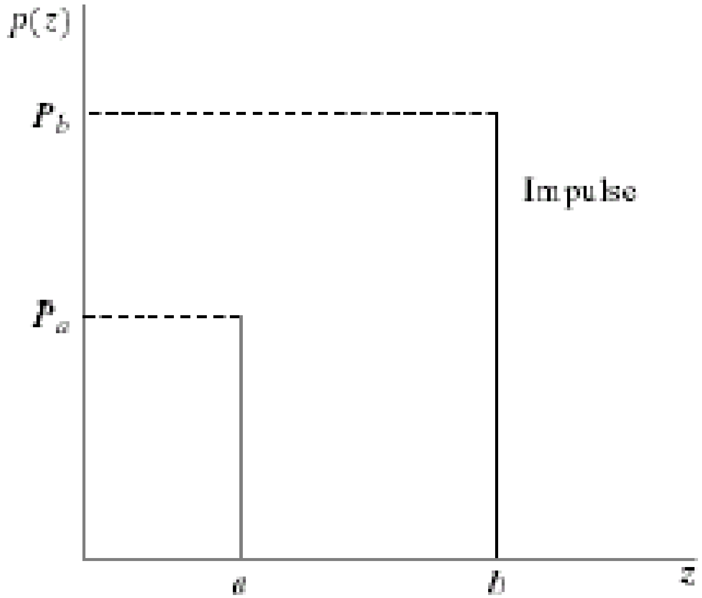
The mean and variance are given by

$$\mu = \frac{a+b}{2}, \quad \sigma^2 = \frac{(b-a)^2}{12}$$



Noise Models: Impulse (Salt and Pepper) Noise

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



If either $P_a=0$ or $P_b=0$ ⇨ unipolar impulse noise

If $P_a \approx P_b \neq 0$ ⇨ bipolar impulse noise or salt-and-pepper noise ⇨ normally, a=0 (black) and b=255 (white)

Applicability of Various Noise Models

Gaussian noise⇨ electronic circuit noise and sensor noise due to poor illumination and/or high temperature

Rayleigh density⇨ characterize noise phenomena in range imaging

Exponential and gamma densities⇨ laser imaging

Impulse noise⇨ occur when quick transients (faulty switching) take place during imaging

Uniform density⇨ the least descriptive of practical situations

Noise Models