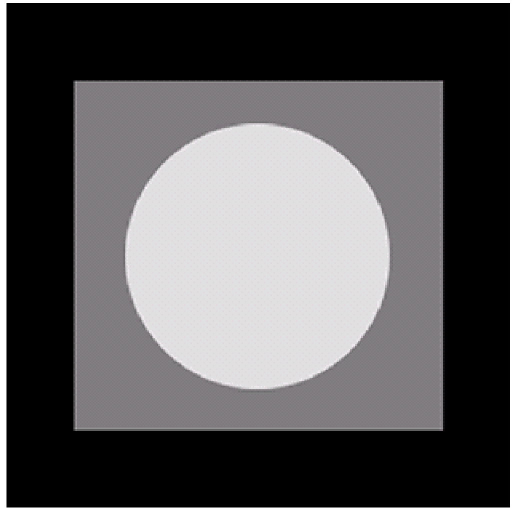
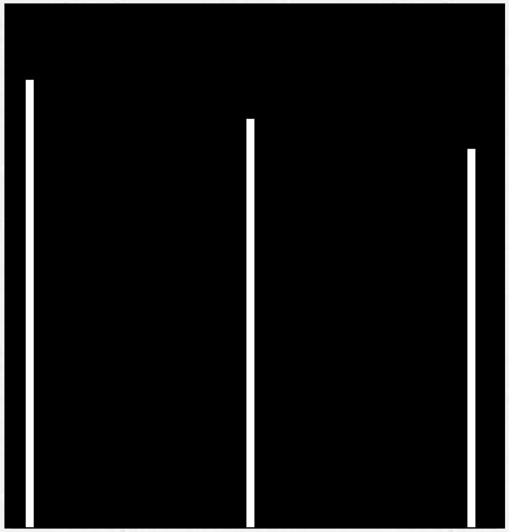
Digital Image Processing

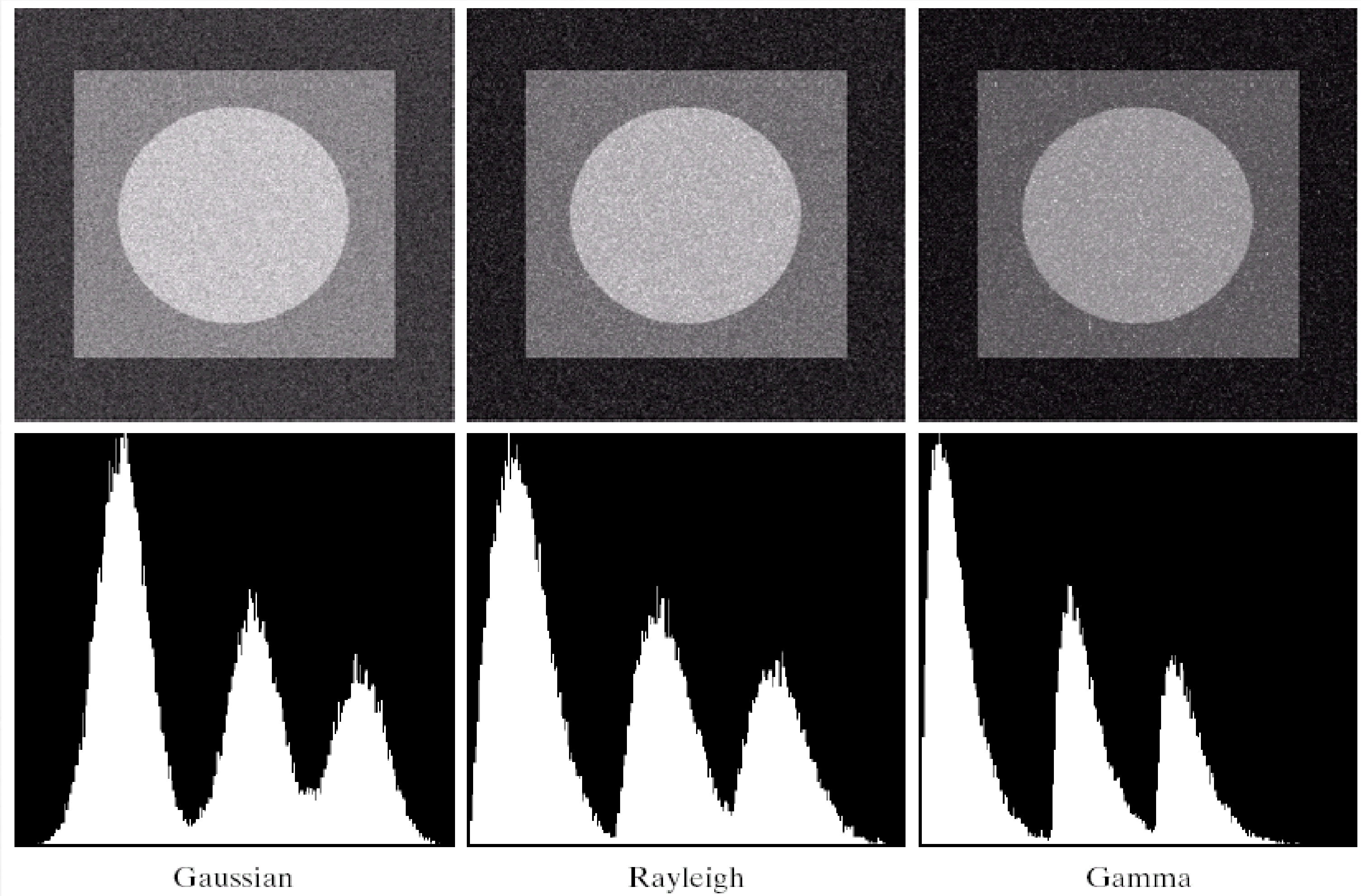
Noise Models

Noise Example

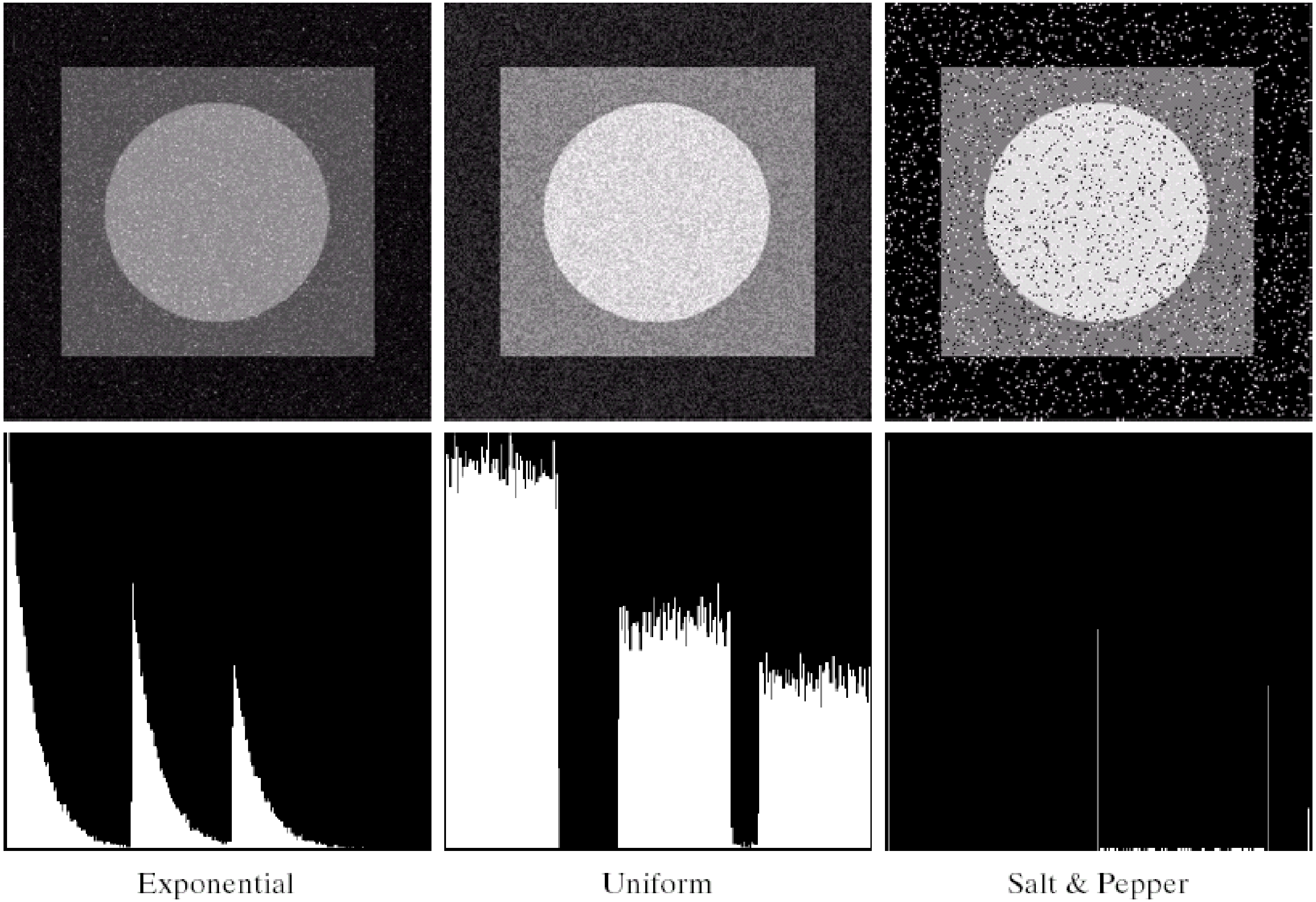




The test pattern to the right is ideal for demonstrating the addition of noise. The following slides will show the result of adding noise based on various models to this image



Gaussian Rayleigh Impulse



Exponential

Uniform

Impulse

Noise

Main source of noise in digital image processing occurs during:

- Image acquisition
- Image transmission

Performance of image sensor is affected due to variety of reasons:

- Environmental conditions
- Quality of sensing elements

Image Noises

- Image noise is random (not present in the object imaged) variation of brightness or color information in images, and is usually an aspect of electronic noise.
- Types
  - Gaussian Noise
  - Rayleigh Noise
  - Erlang (Gamma) Noise
  - Exponential Noise
  - Uniform Noise
  - Impulse (salt-and-pepper) Noise
- In digital cameras
  - Effects of sensor size
  - Sensor fill factor
  - Sensor heat

Noise Model

$$g(x, y) = f(x, y) + \eta(x, y)$$

where $f(x, y)$ is the original image pixel, $\eta(x, y)$ is the noise term and $g(x, y)$ is the resulting noisy pixel

Types Of Models

There are many different models for the image
noise term $\eta(x, y)$:

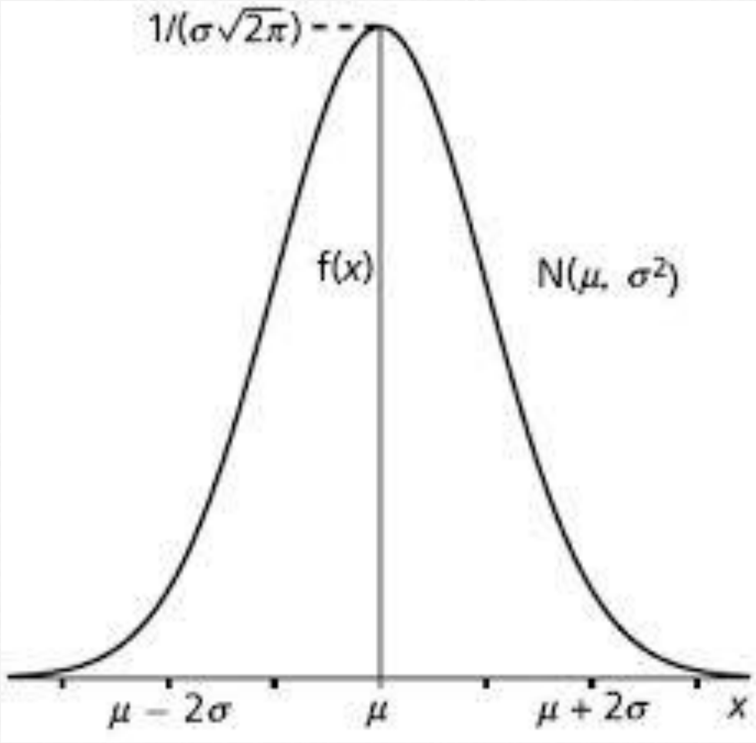
- Gaussian (Most Common model)
- Rayleigh
- Exponential
- Uniform
- Salt & Pepper(Impulse)
- Erlang(Gamma)

Gaussian Noise

- The PDF of a Gaussian random variable, z,

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

- Mean: μ
- Standard deviation: σ
- Variance: σ^2

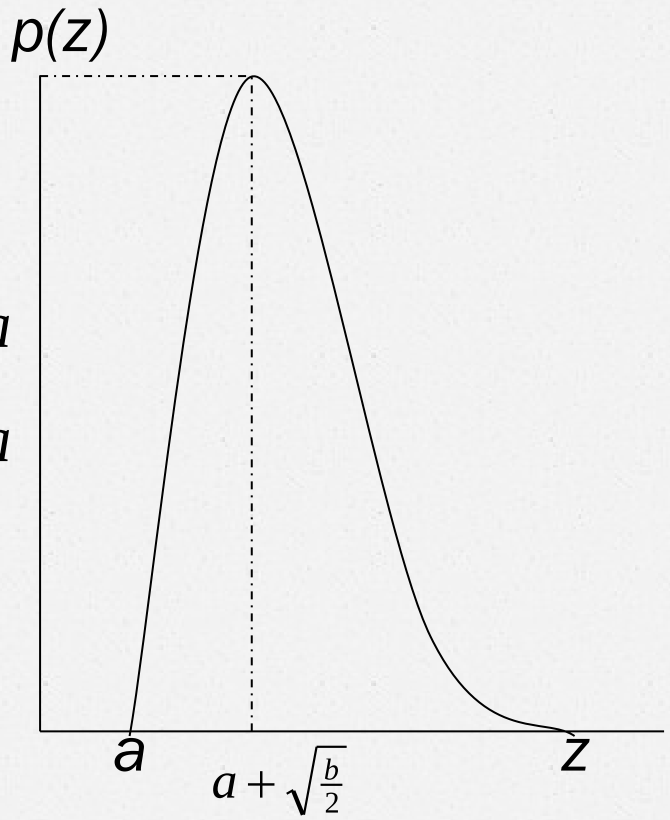


Rayleigh noise

- The PDF of Rayleigh noise,

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

- Mean: $\mu = a + \sqrt{\pi b / 4}$
- Variance: $\sigma^2 = \frac{b(4-\pi)}{4}$

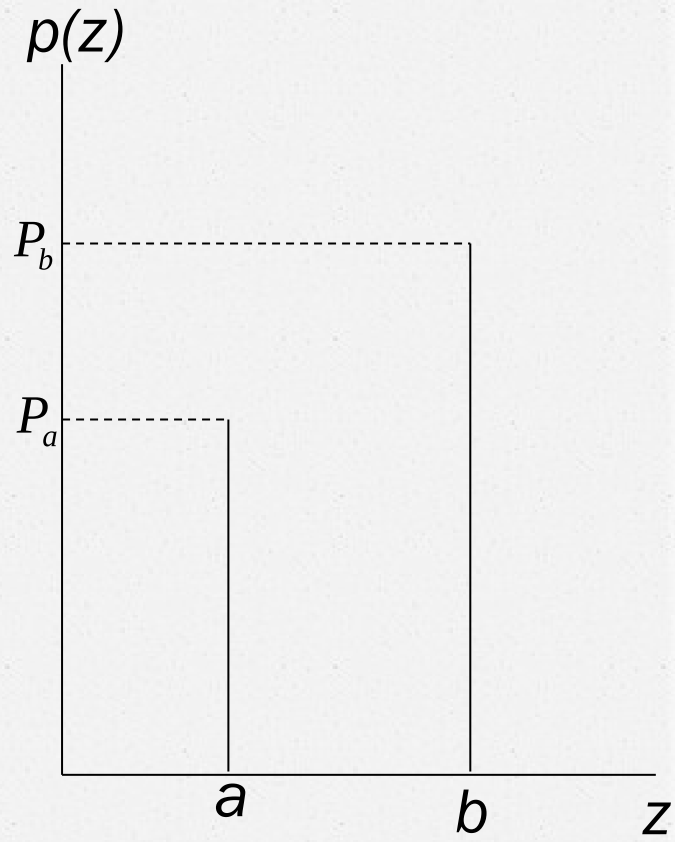


Salt and Pepper

- The PDF of (bipolar) impulse noise,

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

- $b > a$: gray-level will appear
- as a light dot, while level will appear like a dark dot
- Unipolar: either P_a or P_b is zero

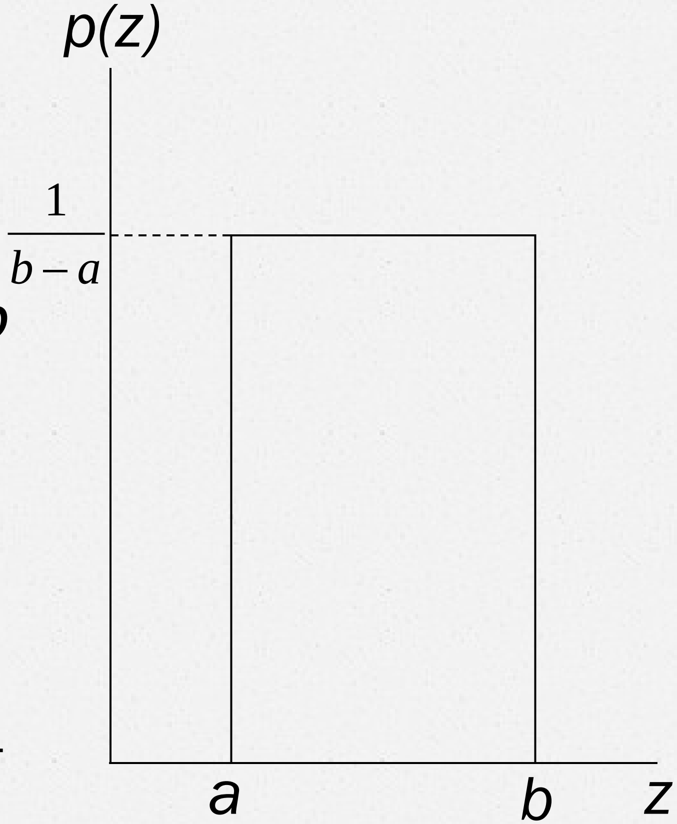


Uniform noise

- The PDF of uniform noise,

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

- Mean: $\mu = \dfrac{a+b}{2}$
- Variance: $\sigma^2 = \dfrac{(b-a)^2}{12}$

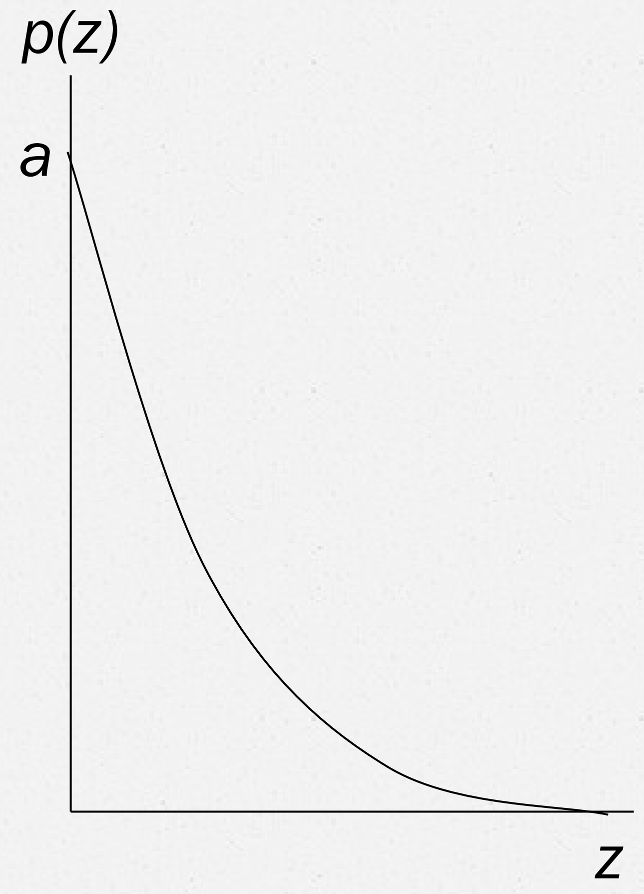


Exponential noise

- The PDF of exponential noise, ,

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

- Mean: $\mu = \dfrac{1}{a}$
- Variance: $\sigma^2 = \dfrac{1}{a^2}$

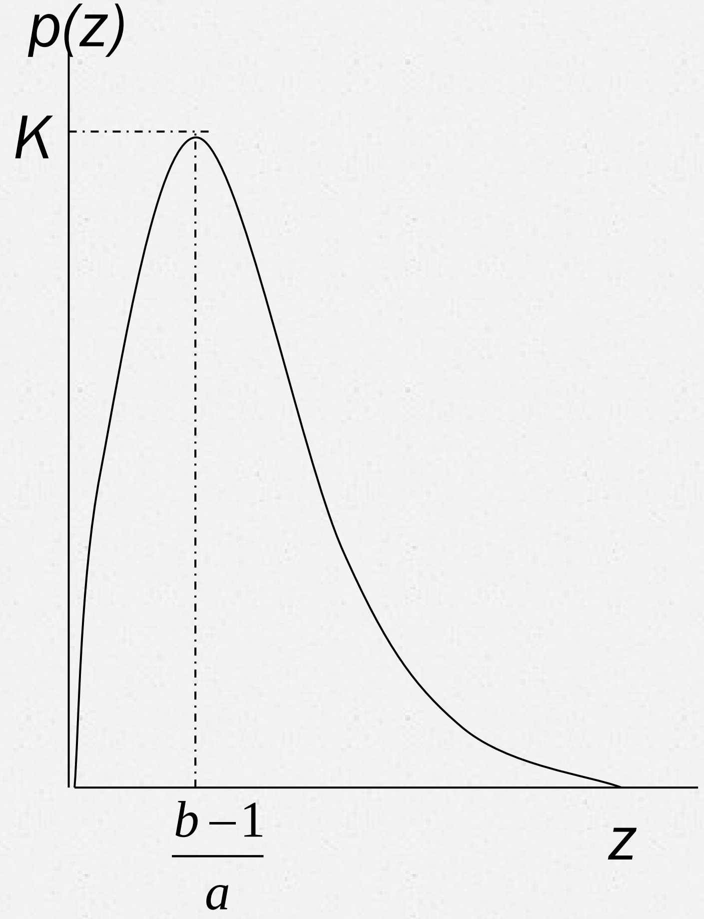


Erlang(Gamma)

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

Mean $\quad \mu=\dfrac{b}{a}$

Variance $\quad \sigma^2=\dfrac{b}{a^2}$



Gaussian Noise

- Also called as additive noise as each pixel is modified such that a certain distribution is added to each pixel
- The most common distribution observed is the Gaussian distribution
- Caused due to poor illumination during capture or due to high temperatures.
- It can also be caused due to noise present in electronic circuits

Poisson Noise

- Also called shot noise or photon noise
- The dominant noise in the lighter parts of an image
- Caused due to variation in the number of photons sensed at a given exposure level
- It follows a Poisson distribution

Salt and Pepper Noise

- Also referred to as impulse noise
- It can be characterized as sparse disturbances in the image leading to discoloration of a few pixels in the image.
- It is caused due to sudden disturbances like dust or a faulty charge coupled device during the capturing of the image.
- The noise effects only a small number of pixels leaving the rest of the picture untouched

Speckle Noise

- Speckle noise is a type of multiplicative noise.
- It causes any distribution to be multiplied by each pixel in the picture.
- It corrupts images like ultrasounds, laser, sonar etc.

noisy image: gaussian noise with mea= 0.005 & vari= 0.005