Marwadi
University

# IMAGE PROCESSING
# 01CE0507

## Unit - 5
## Image Degradation / Restoration

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# Outline

- Noise
- Sources of Noise
- Need of De-Noising
- Image Restoration
- Image Restoration vs. Image Enhancement
- Model of Image Degradation / Restoration Process
- Noise Models
- Types of Restoration Filters
  - Inverse Filter
  - Wiener Filter

# Noise

- What is Noise?
  - Noise is typically defined as a random variation in brightness or colour information and it is frequently produced by technical limits of the image collection sensor or by improper environmental circumstances.
  - Noise means any unwanted signal

# Sources of Noise

- The principal sources of noise in digital images arise during image acquisition and/or transmission.
  - Image acquisition
    - Quality of sensors
    - interference in Sensor (e.g., thermal or electrical interference)
    - Environmental factors may have an impact on the imaging sensor.
    - Low light and sensor temperature may cause image noise.
    - With CCD camera, light levels and sensor temperature are major factors
  - Transmission
    - Interference in channel
    - Transmission channel interference.
    - Environmental conditions (rain, snow etc.)
    - Lightning or other atmospheric disturbance in wireless network
    - Dust particles in the scanner can cause noise in the digital image.

# Need of De-Noising

- Why do we want to denoise?
  - Visually unpleasant
  - Bad for compression
  - Bad for analysis

# Image Restoration

- The main aim of restoration is to improve an image in some predefined way.
- Image restoration tries to reconstruct or recover an image which was degraded using a priori knowledge of degradation.
- Here we model the degradation and apply the inverse process to recover the original image.

# Image Restoration vs. Image Enhancement

- Enhancement:
  - largely a subjective process
  - Priori knowledge about the degradation is not a must (sometimes no degradation is involved)
  - Procedures are heuristic and take advantage of the psychophysical aspects of human visual system.
- Restoration:
  - more an objective process
  - Images are degraded
  - Tries to recover the images by using the knowledge about the degradation

# Model of Image Degradation / Restoration Process

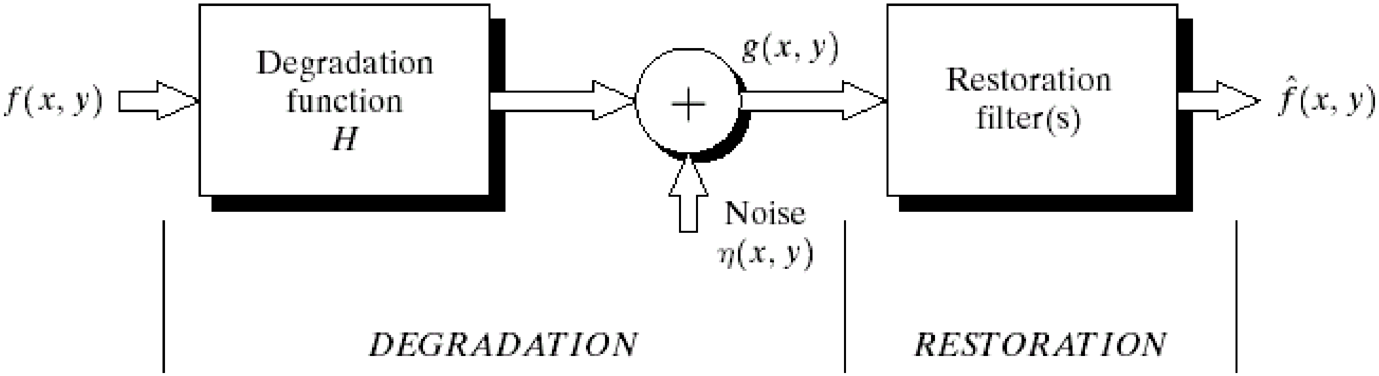



**FIGURE 5.1** A model of the image degradation/ restoration process.

- We model the degradation process by a degradation function h(x,y), an additive noise term, n(x,y)

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

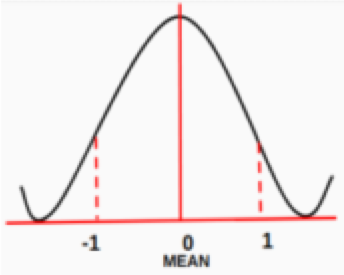
- Where, f(x,y) is the (input) image free from any degradation
  g(x,y) is the degraded image
  * is the convolution operator
- In frequency domain: G(u,v)=H(u,v)F(u,v)+N(u,v)

# Noise Models

- Noise models is a random variable with a probability density function (PDF) that describes its shape and distribution
  - Gaussian Noise /Electronic Noise
  - Speckle Noise
  - Poisson Noise /Quantum (photon) Noise / Shot Noise
  - Rayleigh Noise
  - Erlang Noise / Gamma Noise
  - Impulse Noise / Salt & Pepper Noise
  - Exponential Noise
  - Uniform Noise

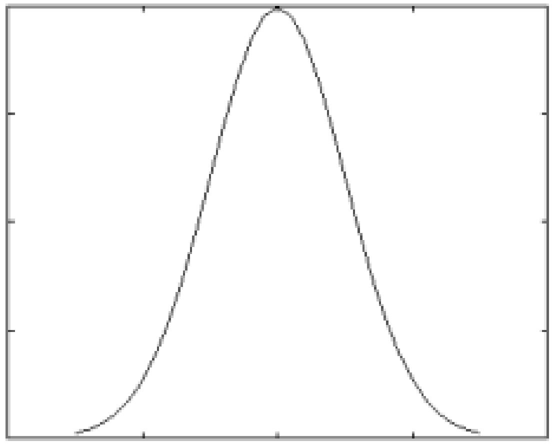
# Gaussian Noise / Electronic Noise

- Gaussian Noise is a statistical noise having a probability density function equal to normal distribution, also known as Gaussian Distribution
- It is also called as **electronic noise** because it arises in amplifiers or detectors.
- Source: thermal vibration of atoms and discrete nature of radiation of warm objects..



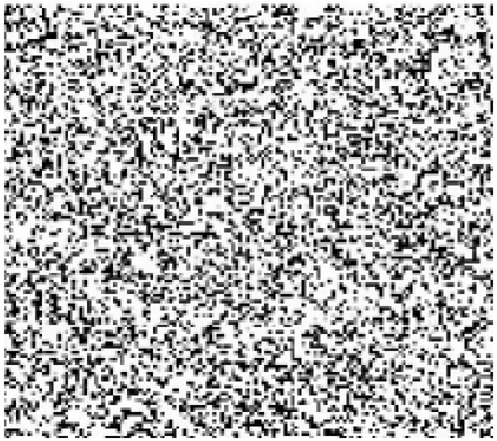
# Gaussian Noise / Electronic Noise (Cont.)

F_Gauss(g)



g →

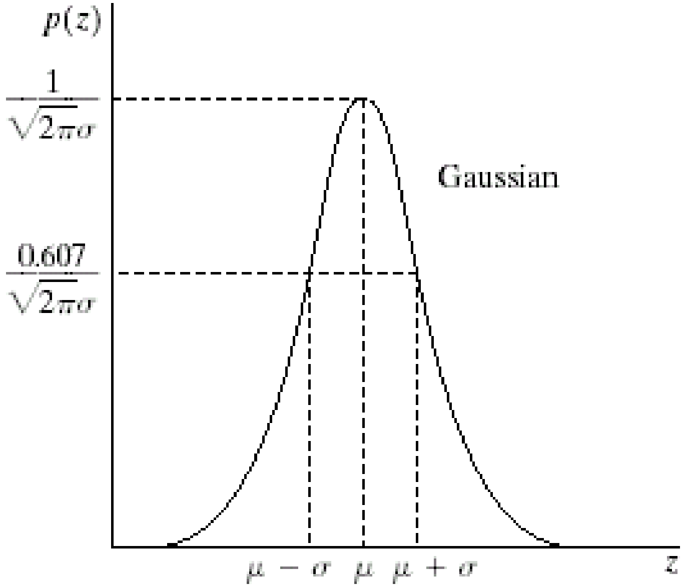
Gaussian Distribution function



Gaussian noise

# Gaussian Noise / Electronic Noise (Cont.)

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

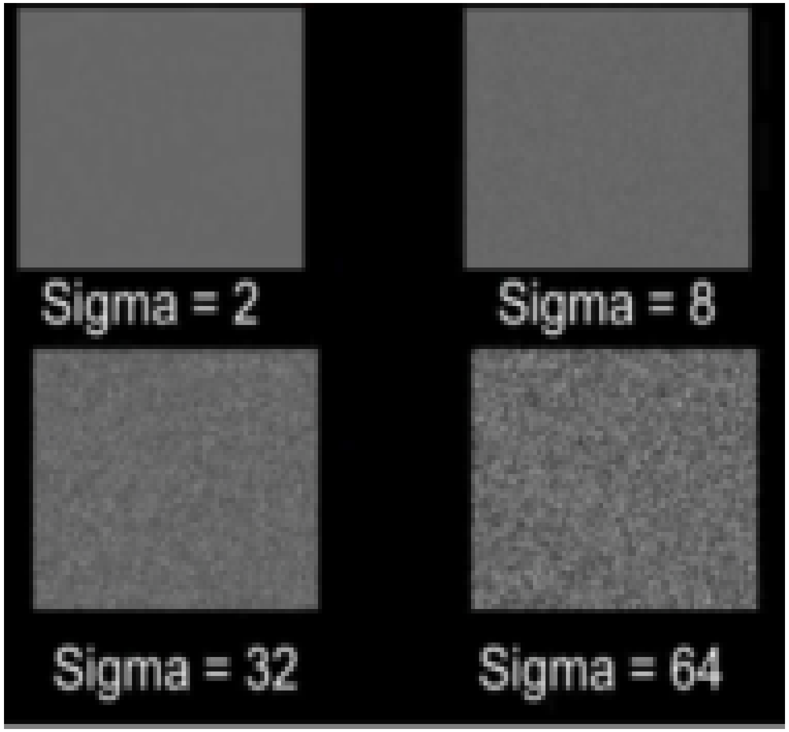



- Where,
  - Z is intensity
  - μ is mean or Average
  - $\sigma^2$ is variance or Standard deviation

- 70% values of z fall in the range [(μ-σ),(μ+σ)]
- 95% values of z fall in the range [(μ-2σ),(μ+2σ)]

# Gaussian Noise / Electronic Noise (Cont.)

- The magnitude of Gaussian Noise depends on the Standard Deviation (sigma).
- Noise Magnitude is directly proportional to the sigma value.

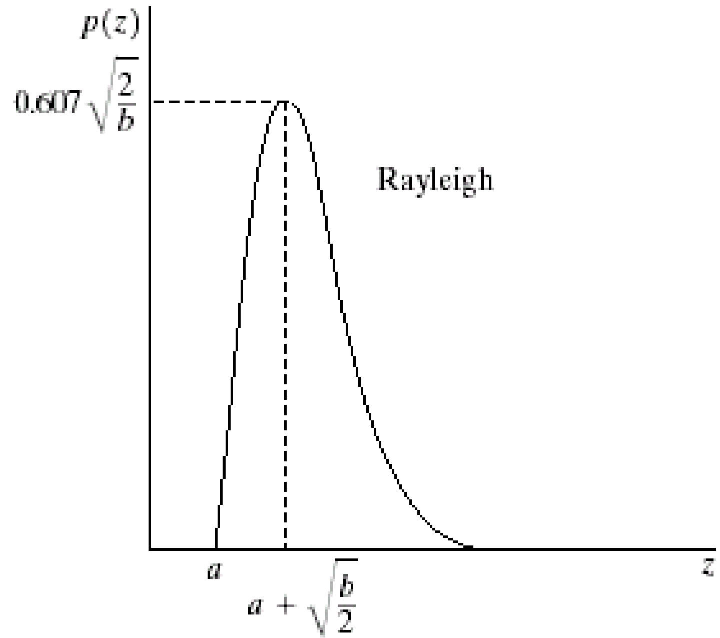


# Rayleigh Noise

- The mean and variance of this density are given by

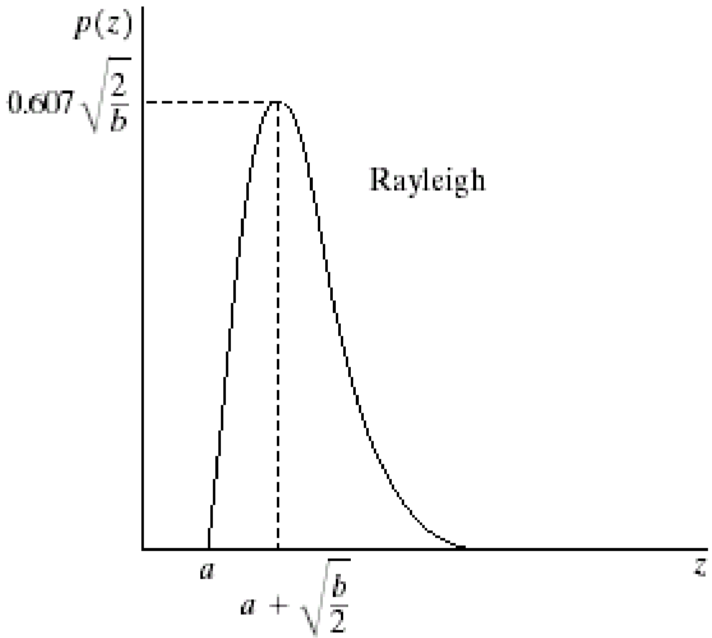
$$p(z) = \begin{cases} \frac{2}{b}(z-a)e^{-(z-a)^2/b} & \text{for } z \ge a \\ 0 & \text{for } z < a \end{cases}$$

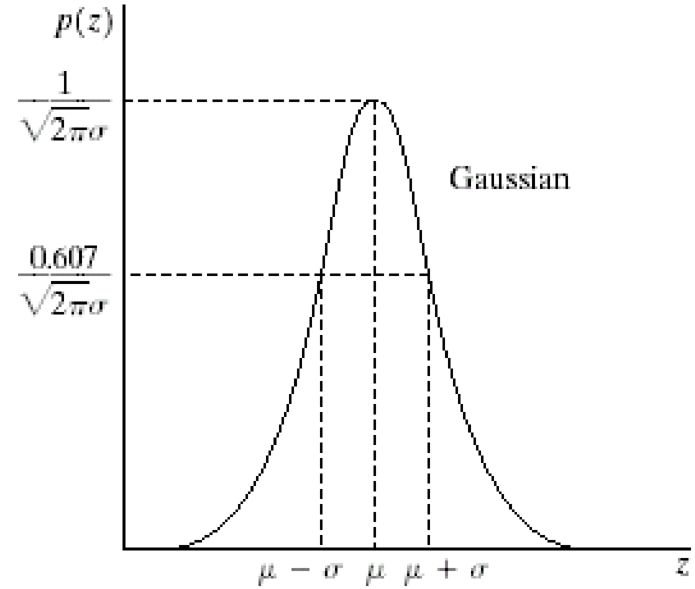
$$\mu = a + \sqrt{\pi b/4} \text{ and } \sigma^2 = \frac{b(4-\pi)}{4}$$




- a and b can be obtained through mean and variance

# Gaussian Noise VS Rayleigh Noise



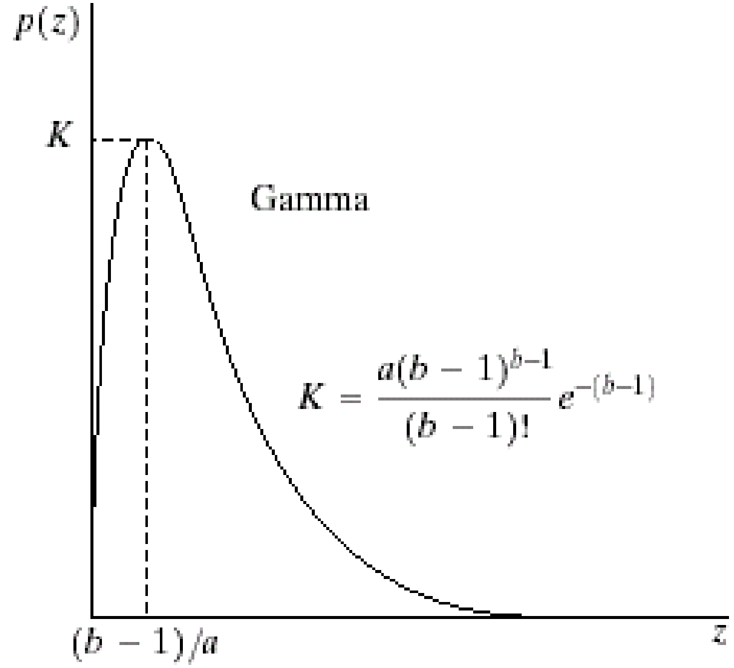



# Erlang Noise / Gamma Noise

- The mean and variance of this density are given by

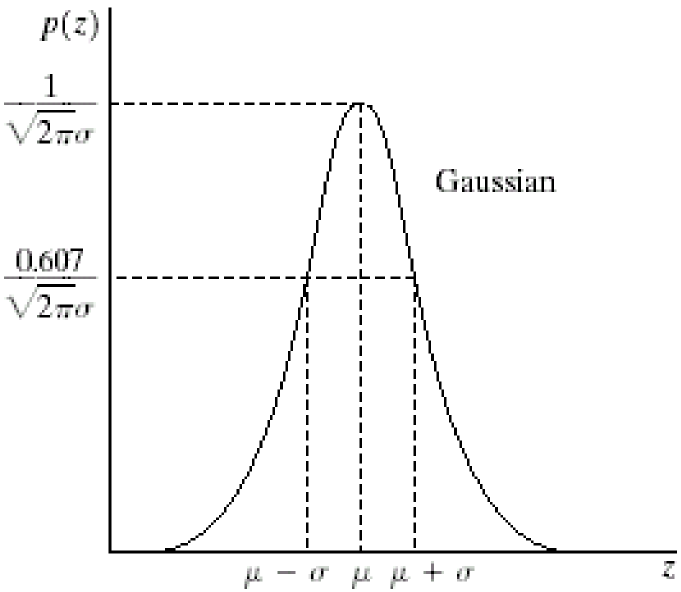
$$p(z)=\begin{cases}\dfrac{a^b z^{b-1}}{(b-1)!}e^{-az} & \text{for } z \ge 0\\ 0 & \text{for } z < 0\end{cases}$$

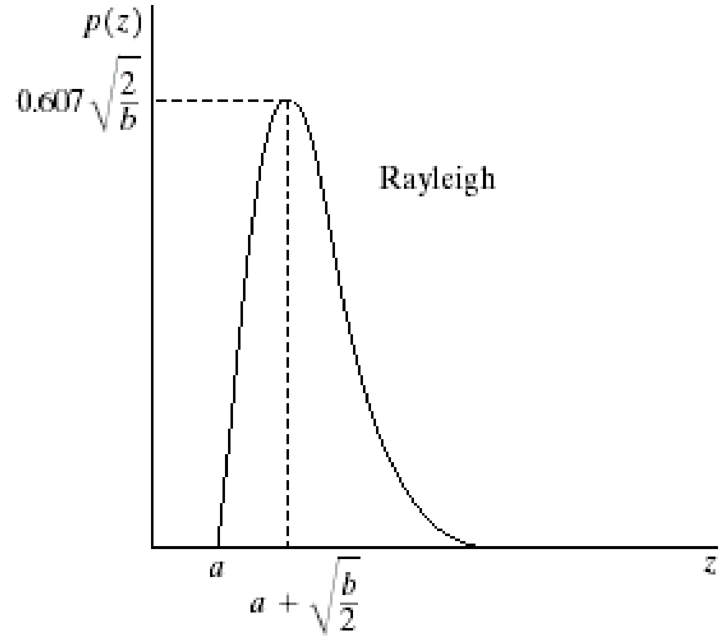
$$\mu = b/a \ \text{ and } \sigma^2 = \frac{b}{a^2}$$

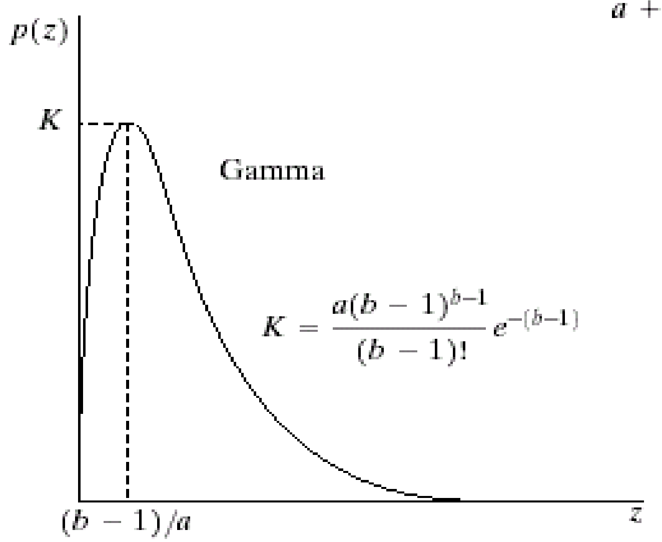



- a and b can be obtained through mean and variance

# Gaussian Noise VS Rayleigh Noise VS Gamma Noise



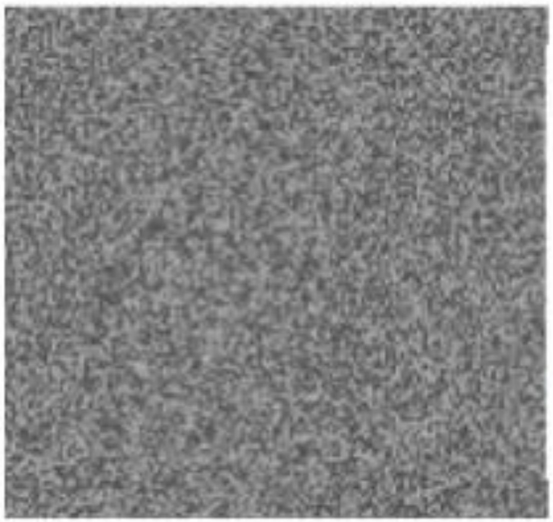
# Speckle Noise

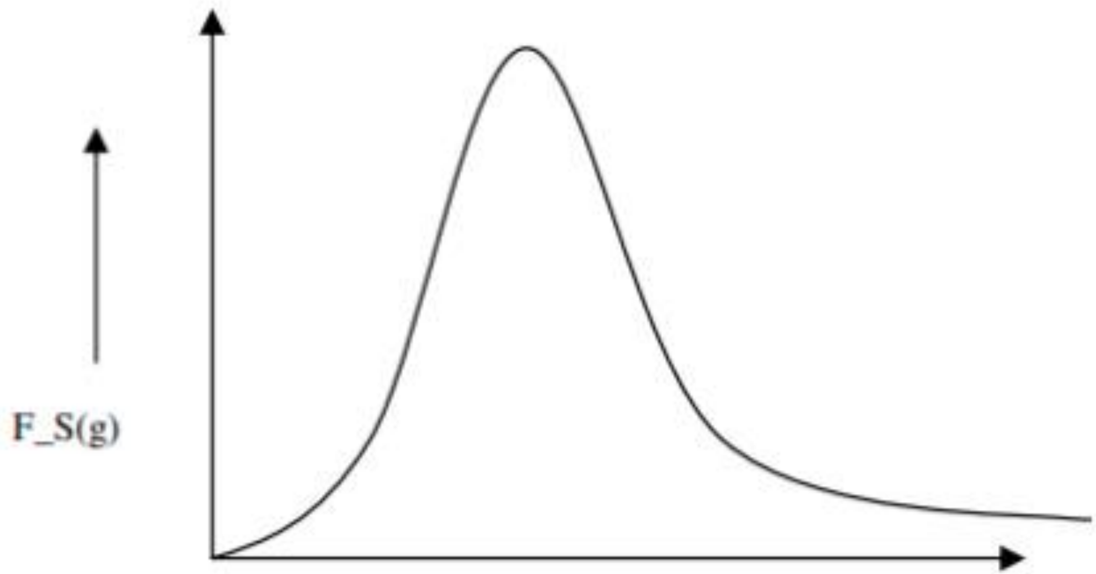
- In diagnostic examinations, this reduces image quality by giving images a backscattered wave appearance caused by many microscopic dispersed reflections flowing through internal organs.
- Source: Their appearance is seen in coherent imaging system such as laser, radar and acoustics, synthetic aperture radar (SAR) images, ultrasound imaging

# Speckle Noise (Cont.)

$$F(g) = \frac{g^{\alpha-1} e^{\frac{-g}{a}}}{(\alpha-1)!\,a^{\alpha}}$$

# Speckle Noise (Cont.)

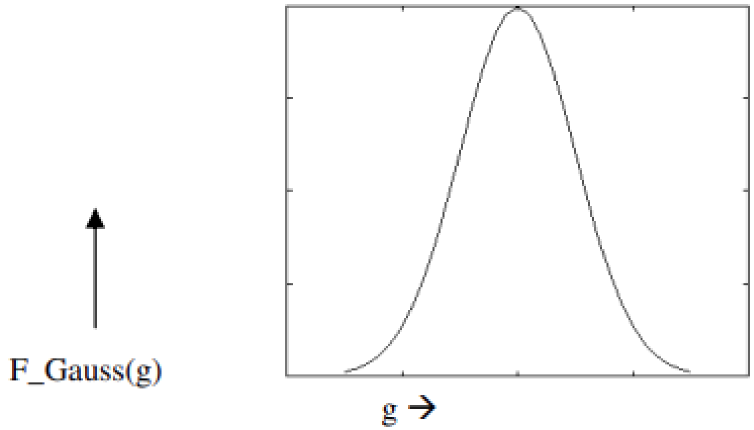




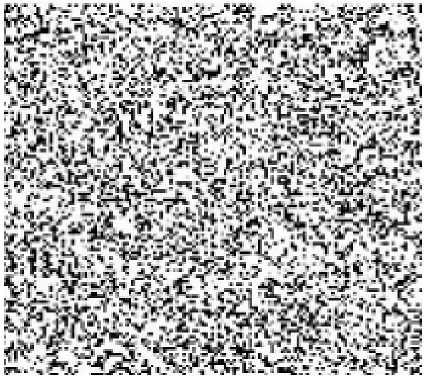

Speckle Noise

# Speckle Noise VS Speckle Noise

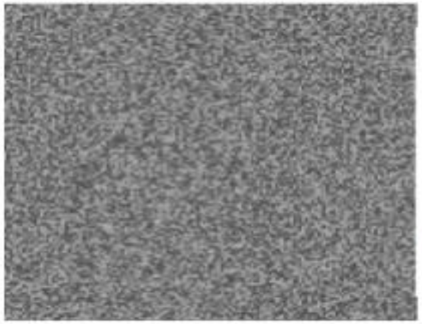




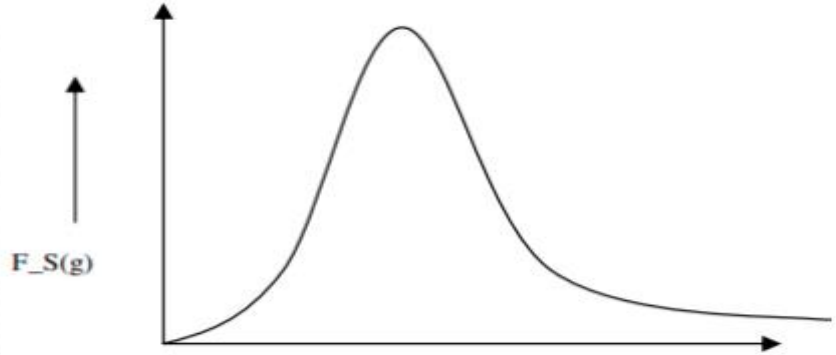

Gaussian Distribution function



Gaussian noise



*Speckle Noise*



# Poisson Noise / Quantum (photon) Noise or Shot Noise

- Poisson noise is produced by the image detectors’ and recorders’ nonlinear responses.
- The appearance of this noise is seen due to the statistical nature of electromagnetic waves such as x-rays, visible lights and gamma rays.
- This noise is also called as **quantum (photon) noise or shot noise**.

# Poisson Noise / Quantum (photon) Noise or Shot Noise (Cont.)

- How this noise add to the Image?
  - The x-ray and gamma ray sources emitted number of photons per unit time. These rays are injected in patient's body from its source, in medical x rays and gamma rays imaging systems.
  - These sources are having random fluctuation of photons.
  - Result gathered image has spatial and temporal randomness.

# Impulse Noise / Salt and Pepper Noise

- There are three types of impulse noises.
  - Salt Noise
  - Pepper Noise
  - Salt and Pepper Noise

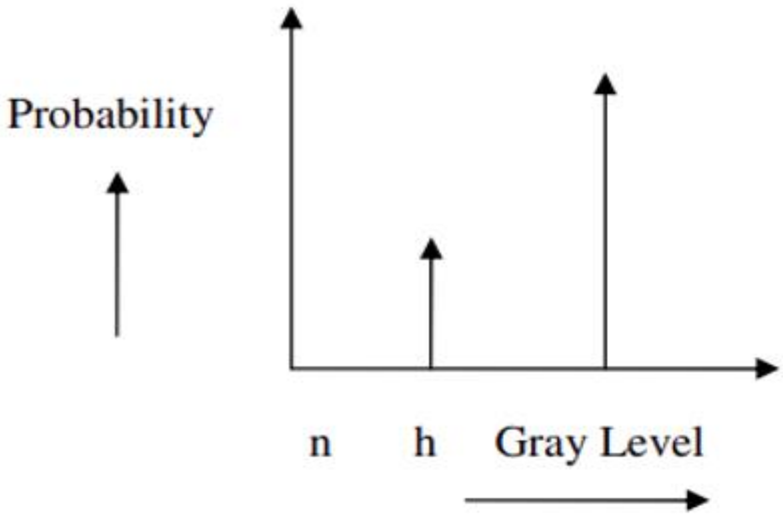
# Salt Noise & Pepper Noise (Cont.)

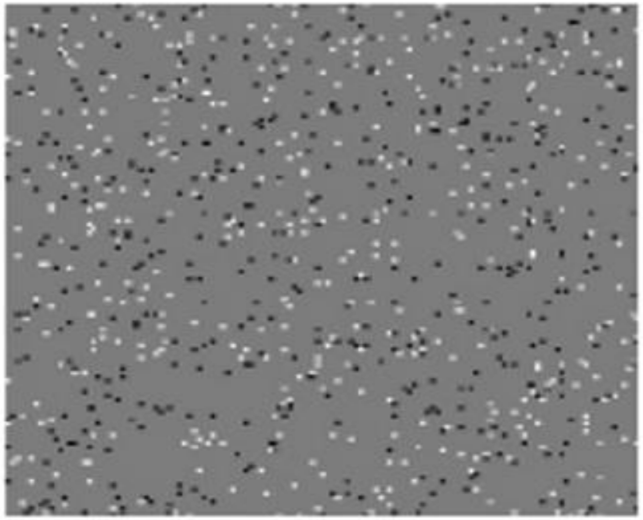
- It manifests as and black pixels that appear at random intervals.
- Salt and Pepper noise is added to an image by addition of both random bright (with 255 pixel value) and random dark (with 0 pixel value) all over the image.
- This model is also known as **data drop noise** because statistically it drop the original data values.
- It is the only type of noise that can be distinguished from others visually

# Salt Noise & Pepper Noise (Cont.)

- Source: Malfunctioning of camera's sensor cell or Errors in data transfer cause this form of noise to appear.

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



# Salt Noise & Pepper Noise (Cont.)

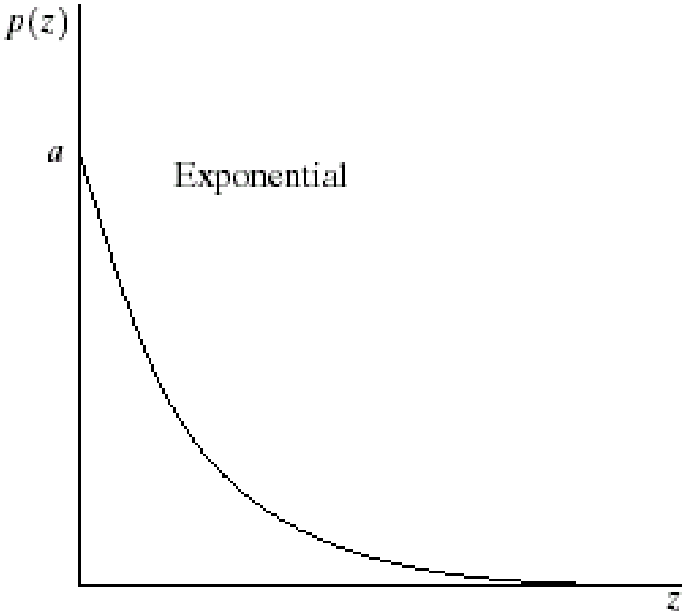
- The use of a median filter or contra harmonic mean filter is an effective noise eradication strategy for this type of noise.

# Exponential Noise

- The mean and variance of this density are given by

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

$$\mu = 1/a \ \text{ and } \sigma^2 = \frac{1}{a^2}$$

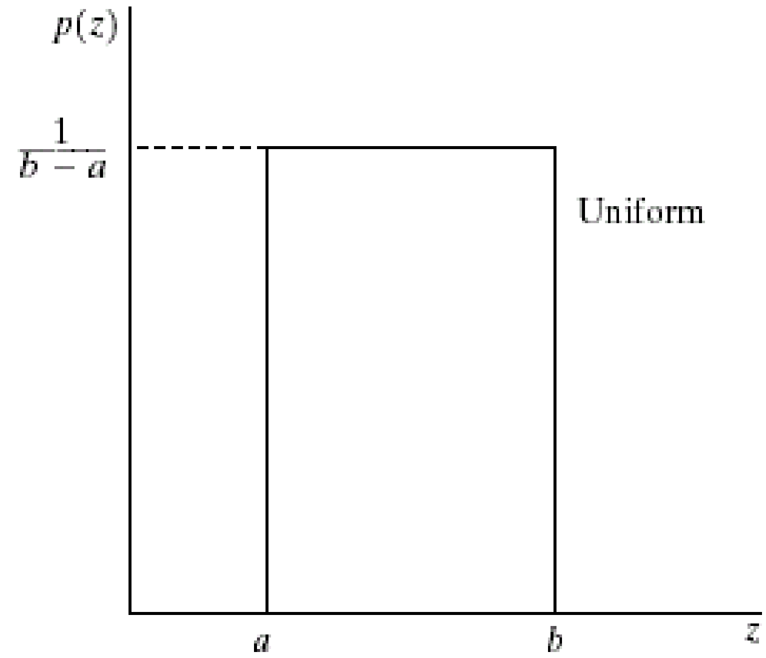


# Uniform Noise

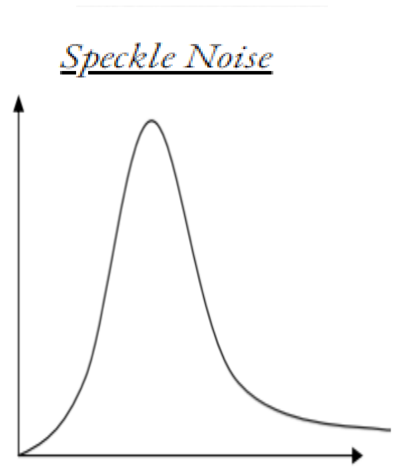
- The mean and variance of this density are given by

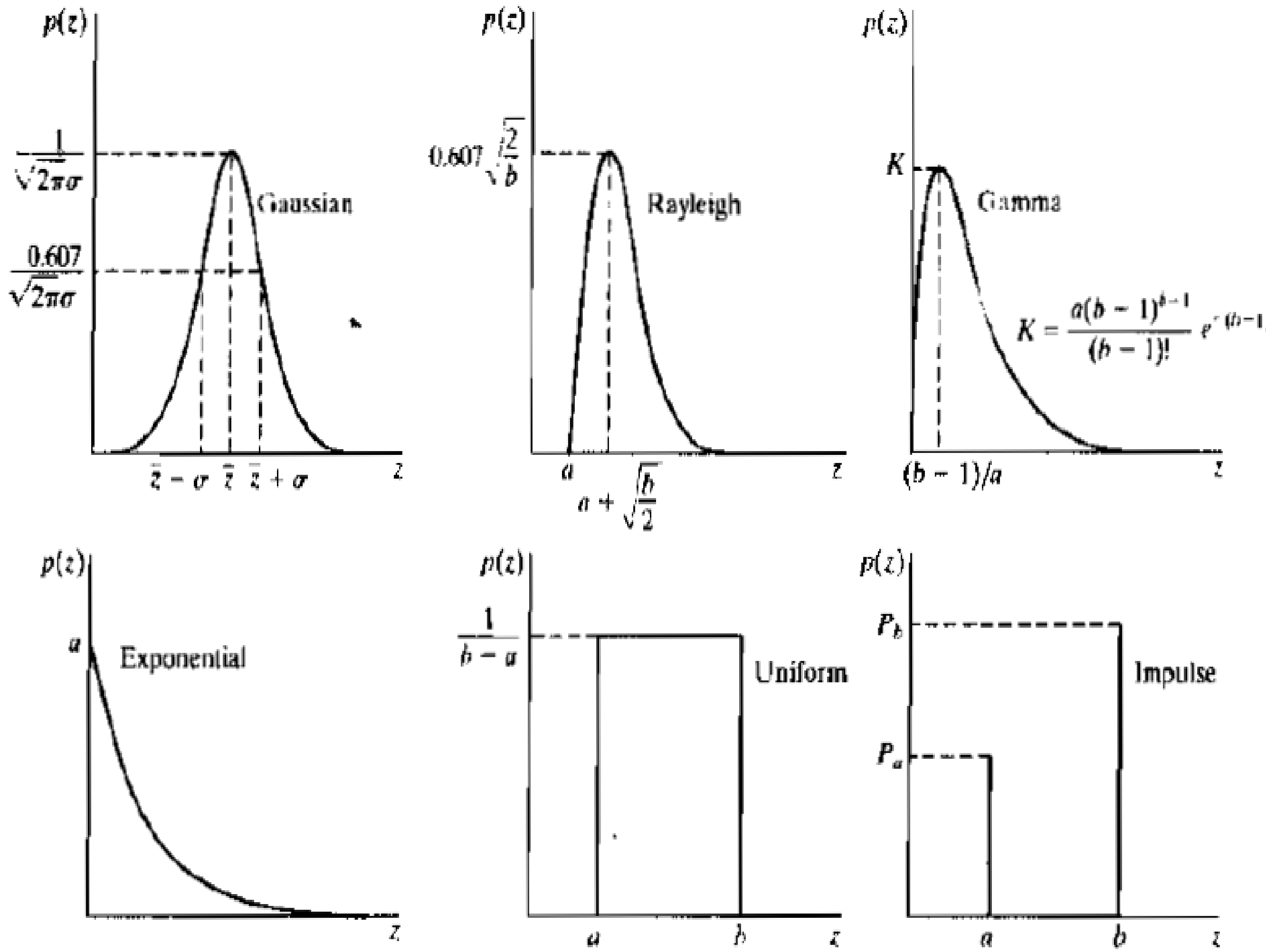
$$p(z) = \begin{cases} \dfrac{1}{b-a} & \text{if } \; a \le z \le b \\ 0 & \text{otherwise} \end{cases}$$

$$\mu = (a+b)/2 \text{ and } \sigma^2 = \frac{(b-a)^2}{12}$$



# Noise Comparison



# Noise Comparison (Cont.)

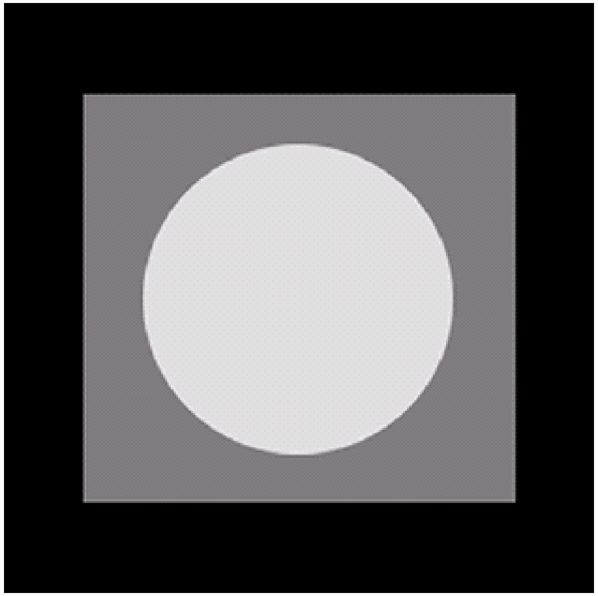
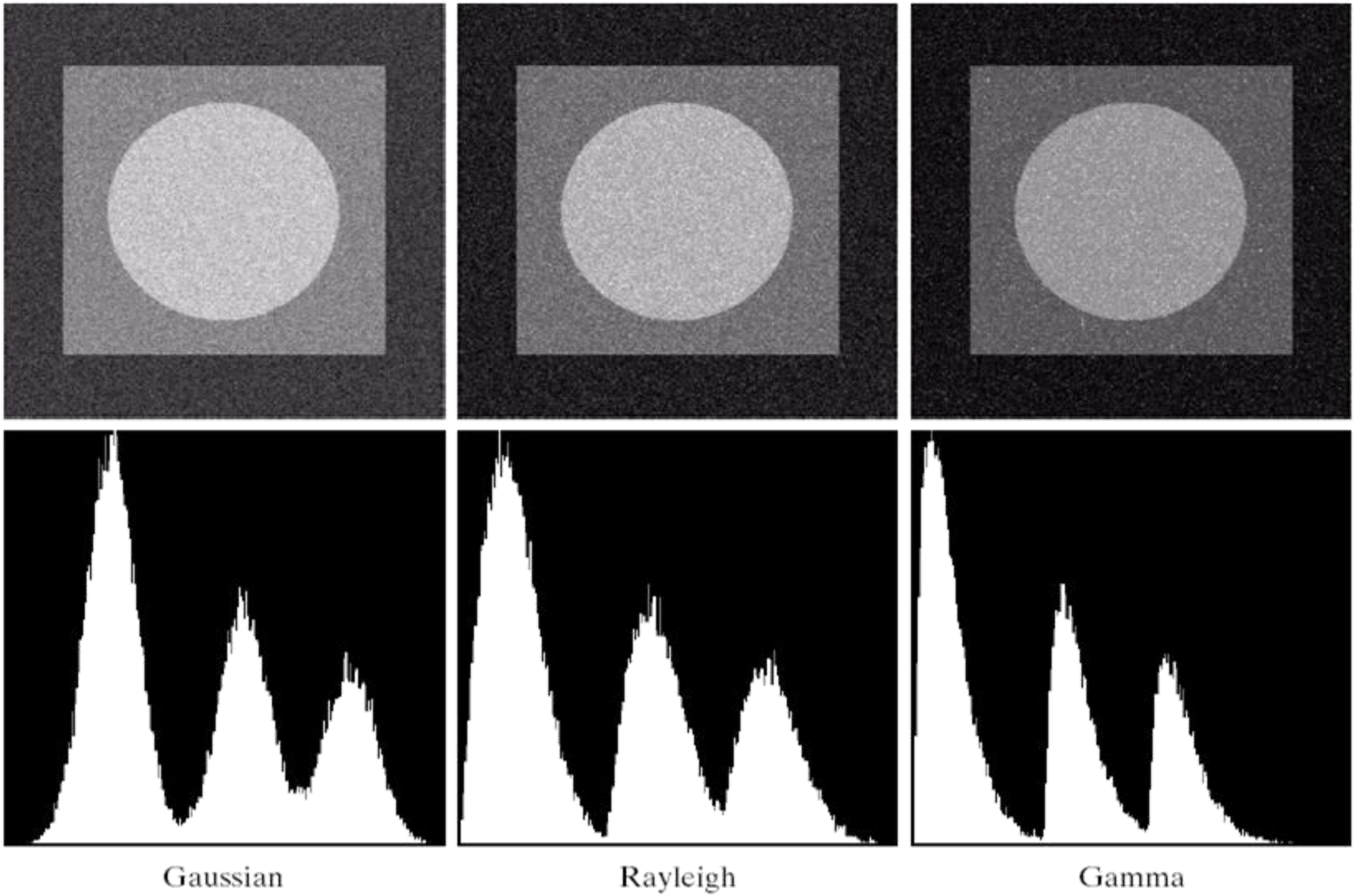
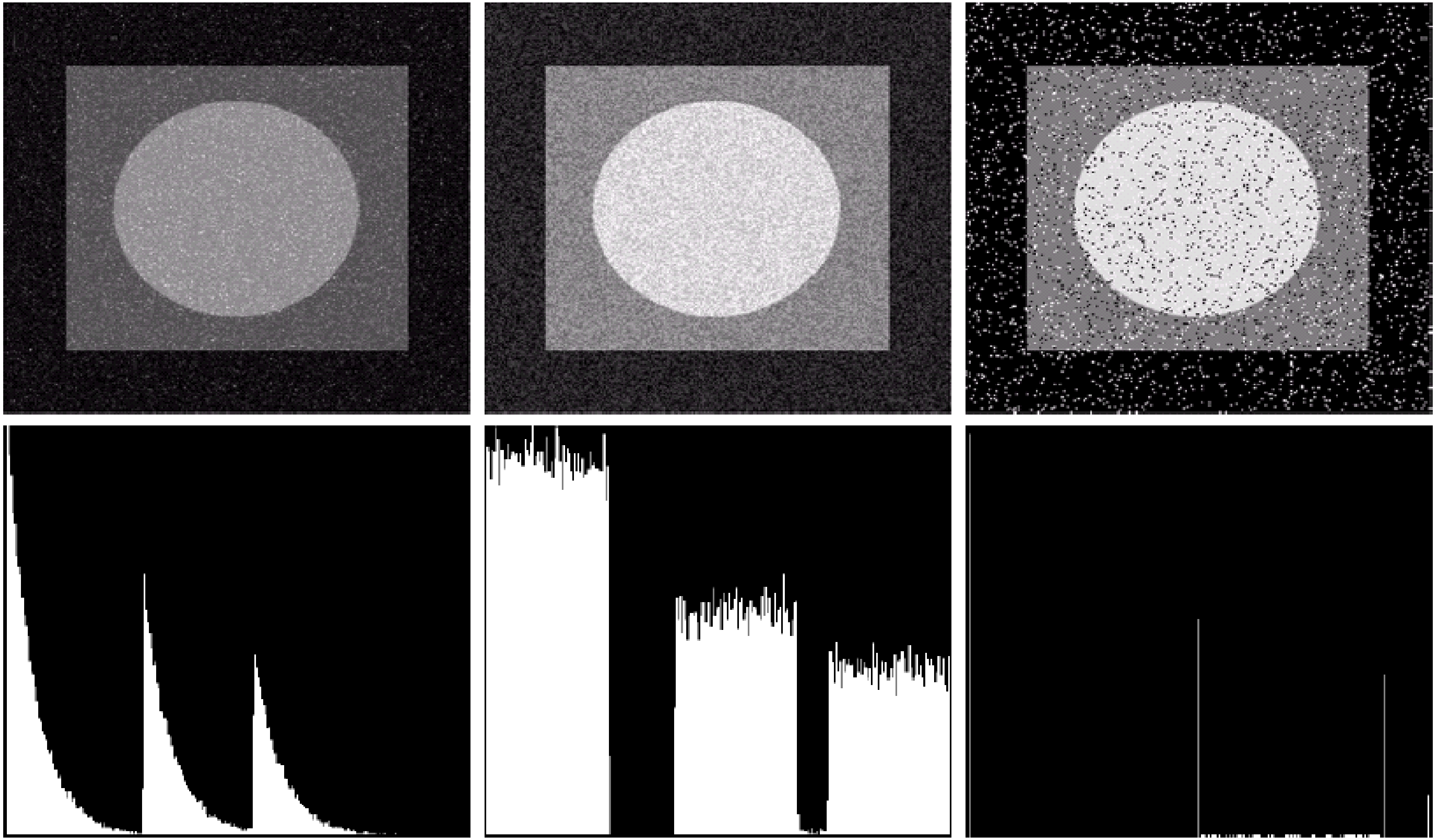


**FIGURE 5.3** Test pattern used to illustrate the characteristics of the noise PDFs shown in Fig. 5.2.


Gaussian
Rayleigh
Gamma

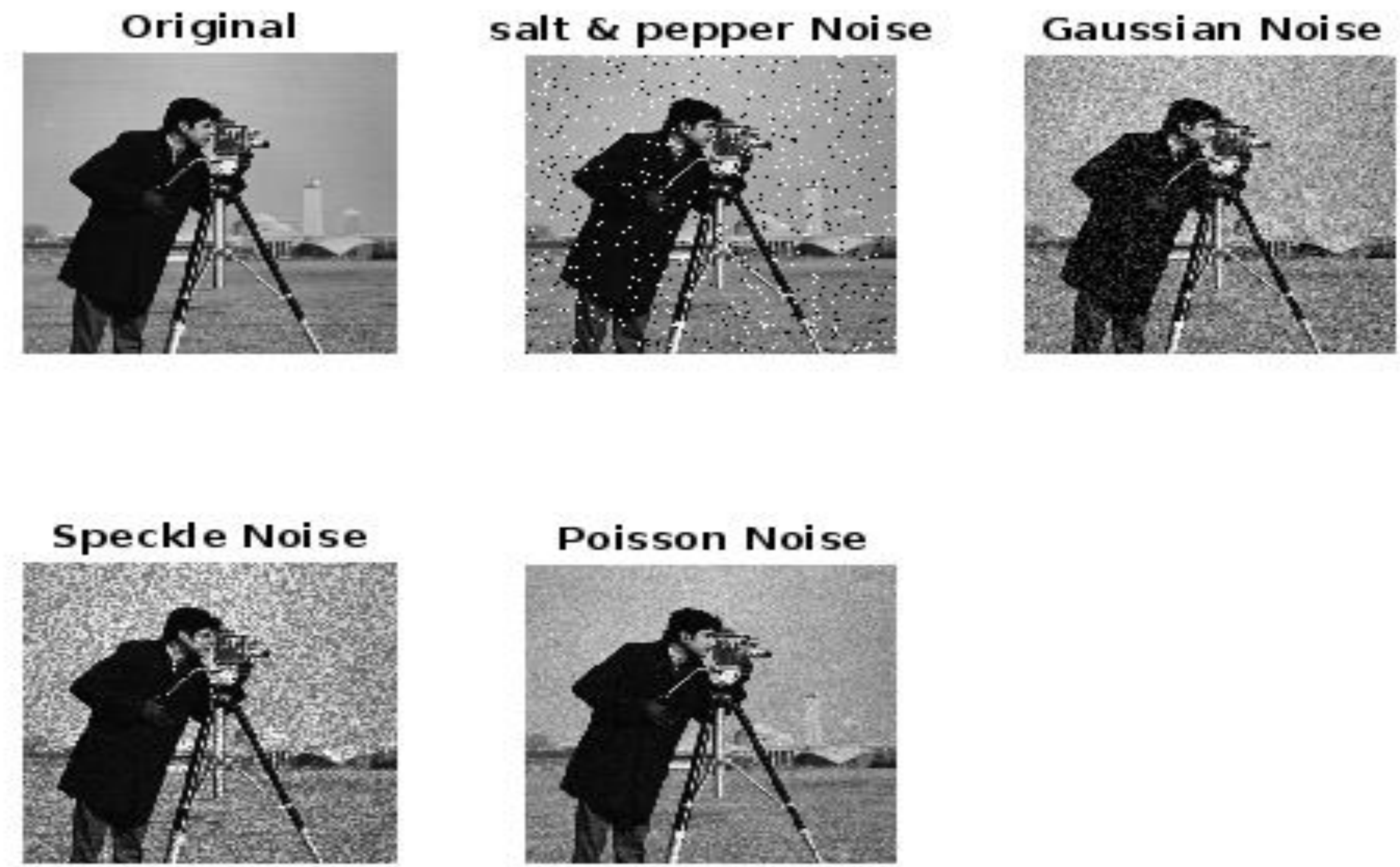


Exponential Uniform Salt & Pepper

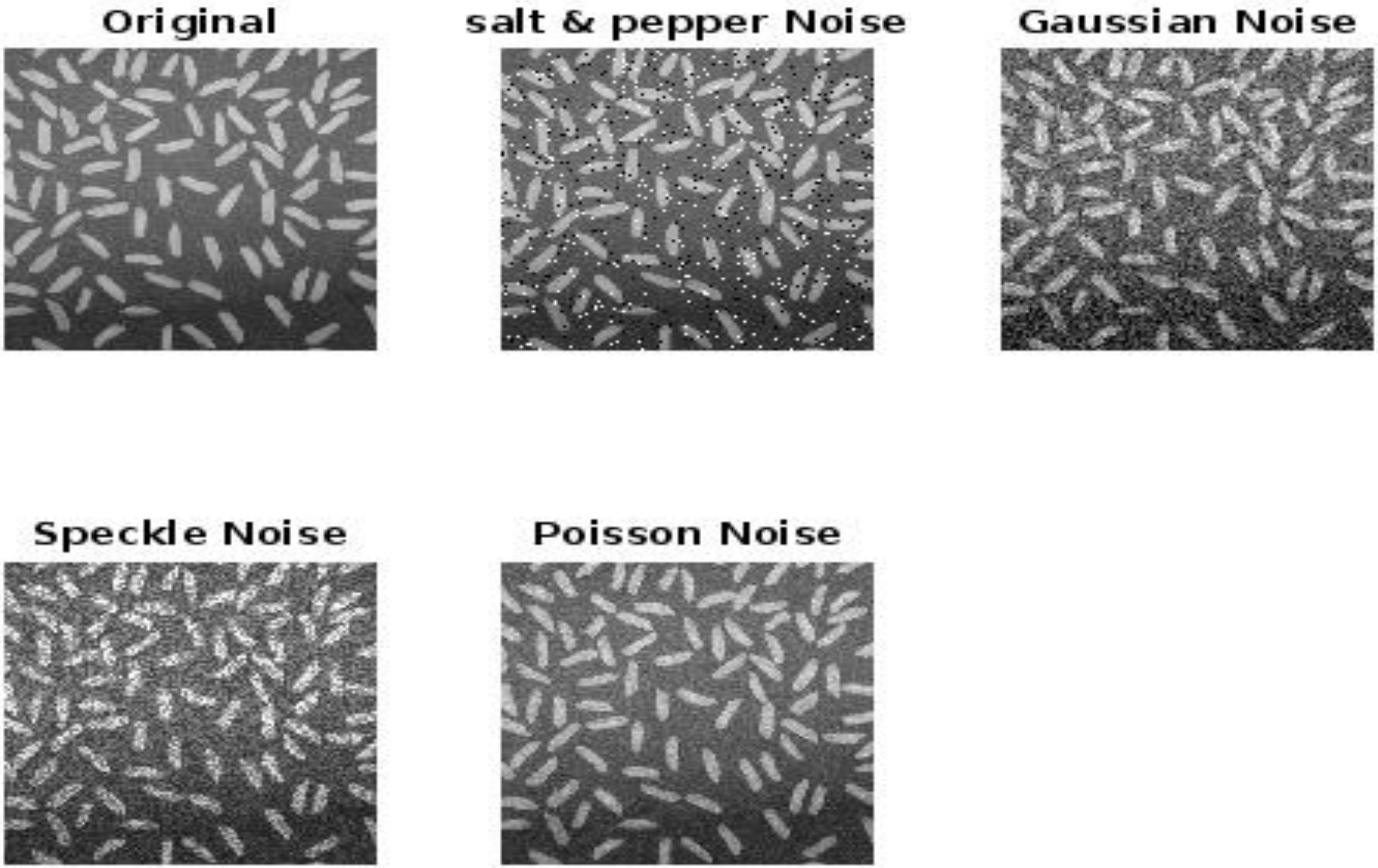
# Noise in MATLAB

- imnoise() function is used to Add noise to image
- Gaussian Noise
  - J = imnoise(I,'gaussian')
- Poisson noise
  - J = imnoise(I,'poisson')
- Salt & Pepper Noise
  - J = imnoise(I,'salt & pepper')
- Speckle Noise
  - J = imnoise(I,'speckle')

# Noise in MATLAB (Cont.)



# Noise in MATLAB (Cont.)

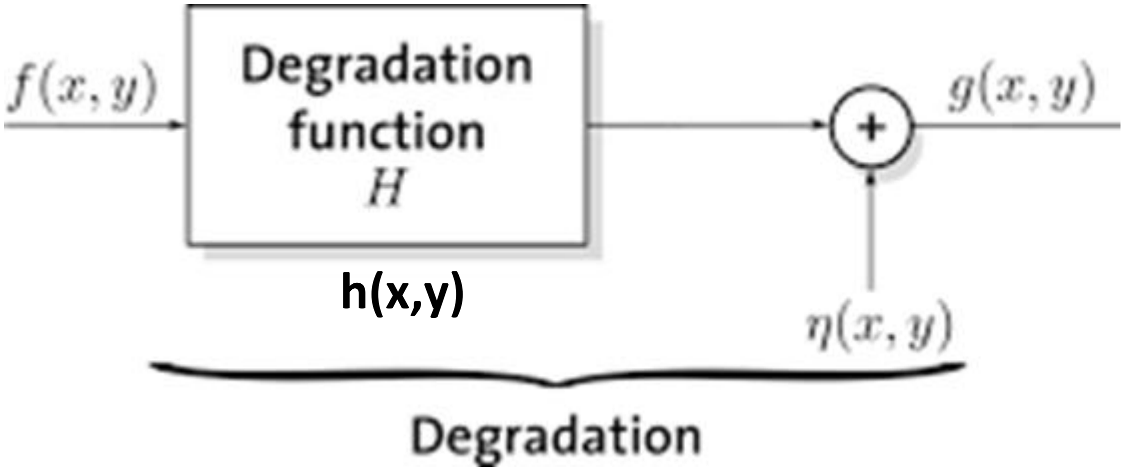


# Noise in MATLAB (Cont.)

```
img = imread('rice.png');
Nc1 = imnoise(img,'salt & pepper');
Nc2 = imnoise(img,'gaussian');
Nc3 = imnoise(img,'speckle');
Nc4 = imnoise(img,'poisson');
subplot(2,3,1); imshow(img); title('Original')
subplot(2,3,2);imshow(Nc1);title('salt & pepper Noise')
subplot(2,3,3);imshow(Nc2);title('Gaussian Noise')
subplot(2,3,4);imshow(Nc3);title('Speckle Noise')
subplot(2,3,5);imshow(Nc4);title('Poisson Noise')
```

# Image Degradation in Spatial Domain

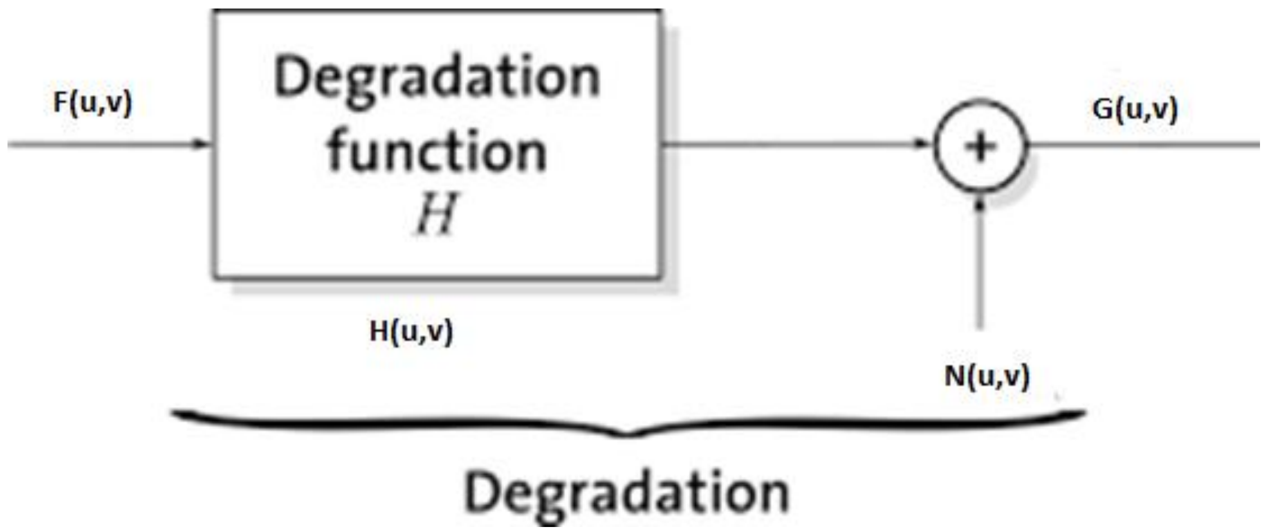
- In Spatial Domain Image Degradation will be represented as,




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

# Image Degradation in Frequency Domain

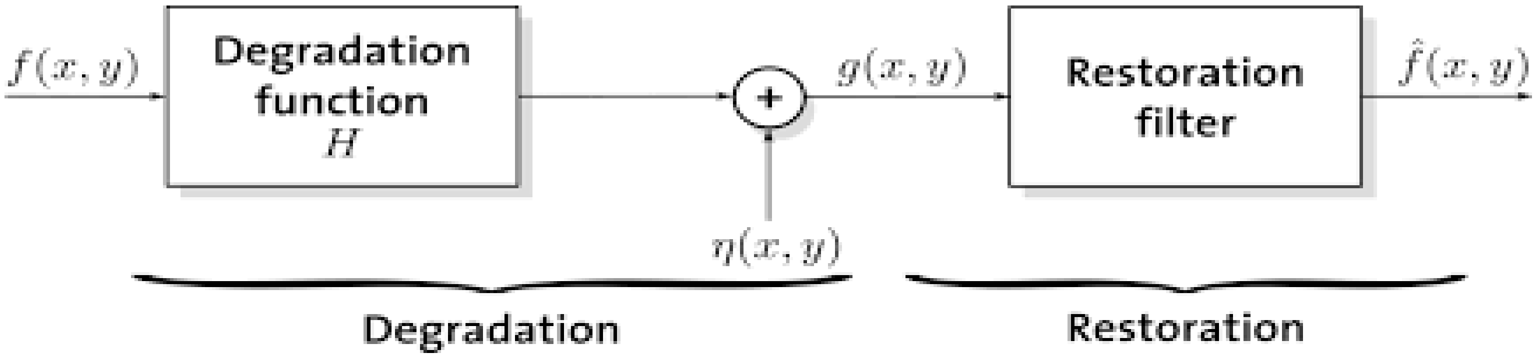
- In Frequency Domain Image Degradation will be represented as,




$$G(u,v) = F(u,v) \, . \, H(u,v) + N(u,v)$$

# Image Restoration in Spatial Domain

- In Spatial Domain Image Restoration will be represented as,



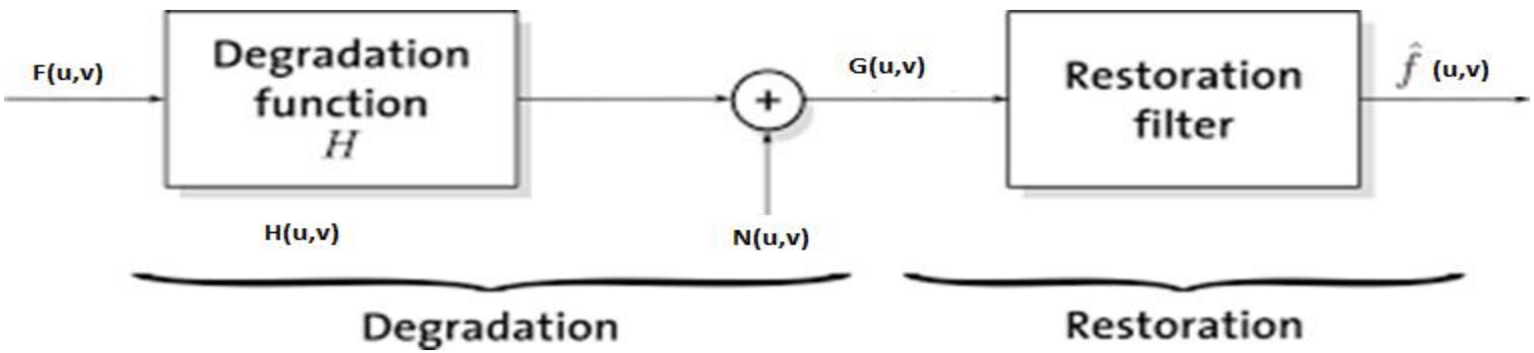

g(x,y) = f(x,y) * h(x,y) + n(x,y) and

f'(x,y) = Restoration Filter [ g(x,y) ]

= Restoration Filter [f(x,y) * h(x,y) + n(x,y) ]

# Image Restoration in Frequency Domain

- In Frequency Domain Image Restoration will be represented as,




G(u,v) = F(u,v) . H(u,v) + N(u,v) and

F‘(u,v) = Restoration Filter [ G(u,v) ]

= Restoration Filter [F(u,v) . H(u,v) + N(u,v) ]

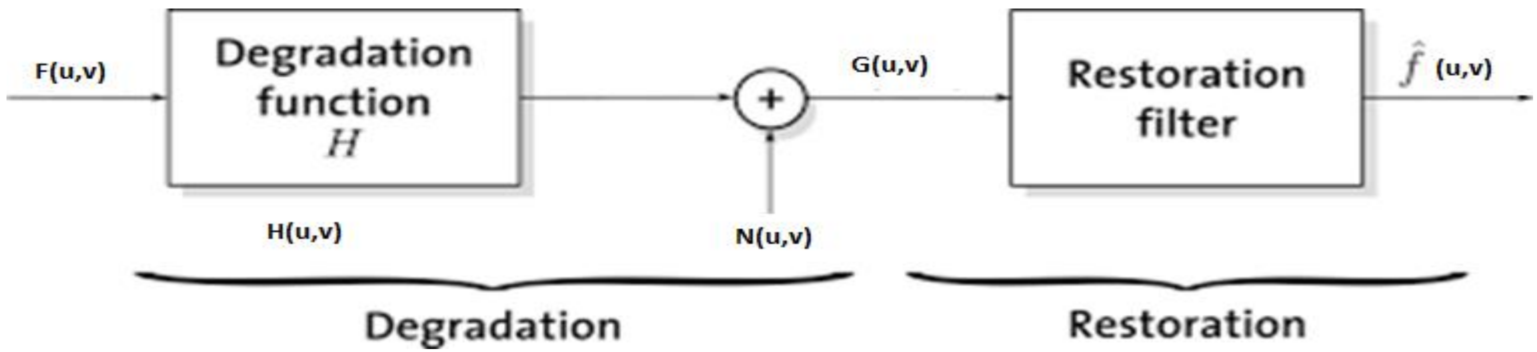
# Types of Restoration Filters

- Restoration Filters are the type of filters that are used for operation of noisy image and estimating the clean and original image.
- Types of Restoration Filters
  - There are three types of Restoration Filters
    - Inverse Filter
    - Wiener Filter / Minimum Mean Square Error Filter

# Inverse Filter

- Inverse Filtering is the process of receiving the input of a system from its output.
- The idea of the inverse filtering method is to recover the original image from the blurred image by inversing blurring filter.
- We assume that no additional noise is present in the system.
- It is the simplest approach to restore the original image once the degradation function is known.

# Inverse Filter (Cont. )




G(u,v) = F(u,v) . H(u,v) + N(u,v)

F‘(u,v) = Restoration Filter [ G(u,v) ]

= Restoration Filter [F(u,v) . H(u,v) + N(u,v) ]

But , In Inverse Filter we assume that no additional noise is present in the system means N(u,v) = 0

G(u,v) = F(u,v) . H(u,v) => F(u,v) = [G(u,v) / H(u,v) ] and ,

F’(u,v)= Inverse Filter [ G(u,v) ]

= Inverse Filter[F(u,v) . H(u,v) ]

# Minimum Mean Square Error Filter / Wiener Filter

- This restoration method assumes that noise which is present in the system is additive white Gaussian noise
- It minimizes mean square error between original and restored images.
- Wiener filtering normally requires prior knowledge of the power spectra (spectral power densities) of the noise and the original image.
- Spectral power density is a function that describes power distribution over the different frequencies.

# Minimum Mean Square Error Filter / Wiener Filter (Cont.)

- The objective of Minimum Mean Square Error Filter / Wiener Filter is to find F' which is close approximation of Original Image such that the error should be minimized.

$$\text{Mean Square Error } e^2 = E\{(F - F')^2\}$$

# Minimum Mean Square Error Filter / Wiener Filter (Cont.)

- Assumptions in Minimum Mean Square Error Filter / Wiener Filter
  – Noise and image are uncorrelated.
  – Any one of them have zero mean
  – Gray Levels in the estimate are liner functions of the degraded Image.

# Minimum Mean Square Error Filter / Wiener Filter (Cont.)

$$\hat{F}(u,v) = \left[ \frac{H^*(u,v)}{|H(u,v)|^2 + [S_\eta(u,v) / S_f(u,v)]} \right] G(u,v)$$

$$S_\eta(u,v) = power\ spectrum\ of\ the\ noise$$

$$S_f(u,v) = power\ spectrum\ of\ the\ undegraded\ image$$

# Minimum Mean Square Error Filter / Wiener Filter (Cont.)



$$\hat{F}(u,v) = \left[ \frac{H^*(u,v)}{|H(u,v)|^2 + [S_\eta(u,v)/S_f(u,v)]} \right] G(u,v)$$

$$So, Consider --> S_\eta(u,v)/S_f(u,v) = 0$$

$$\hat{F}(u,v) = \left[ \frac{H^*(u,v)}{|H(u,v)|^2 + [0]} \right] G(u,v)$$

$$\hat{F}(u,v) = \left[ \frac{H^*(u,v)}{H^*(u,v) \bullet H(u,v)} \right] G(u,v)$$

$$\hat{F}(u,v) = \left[ \frac{1}{H(u,v)} \right] G(u,v)$$

If the noise is zero, then the Wiener Filter reduces to the inverse filter.

# Drawbacks of Restoration Filters

- Not effective when images are restored for the human eye.
- Cannot handle the common cause of non-stationary signals and noise.
- Cannot handle spatially variant blurring point spread function.


Thank you