DIGITAL IMAGE PROCESSING-1

Unit 4: Lecture 39-40

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Unit 4: Image Filtering and Restoration

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Last Session

- Image Enhancement: Frequency domain methods
  - Sharpening using frequency domain filters
  - Homomorphic Filtering

This Session

- Introduction to Image Restoration
- Degradation model
- Noise Models

Image Enhancement

- Image enhancement is the process of enhancing the **quality** of a given image for analysis

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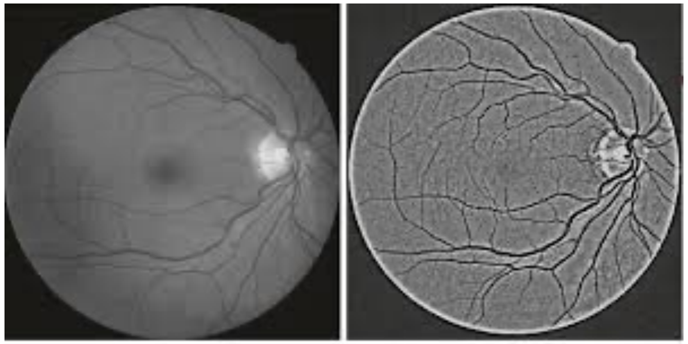
Enhanced Images

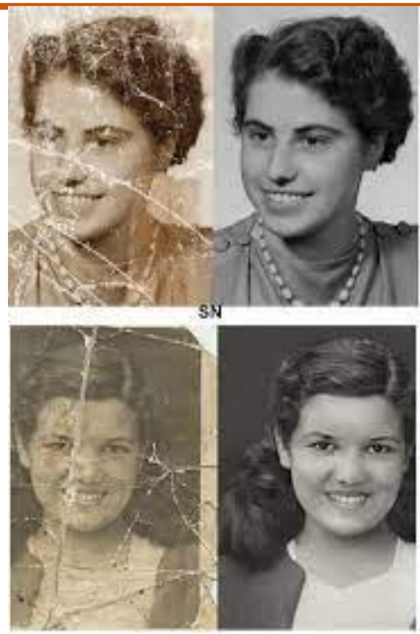
(a) (b) (c)



Original Enhanced with SUACE

Sample Images

Restored Images



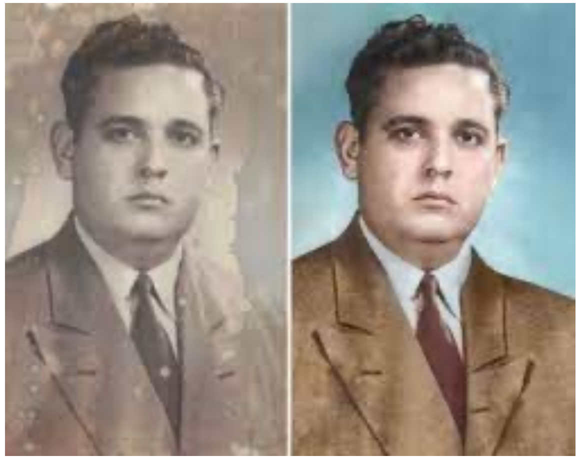


Image Degradation

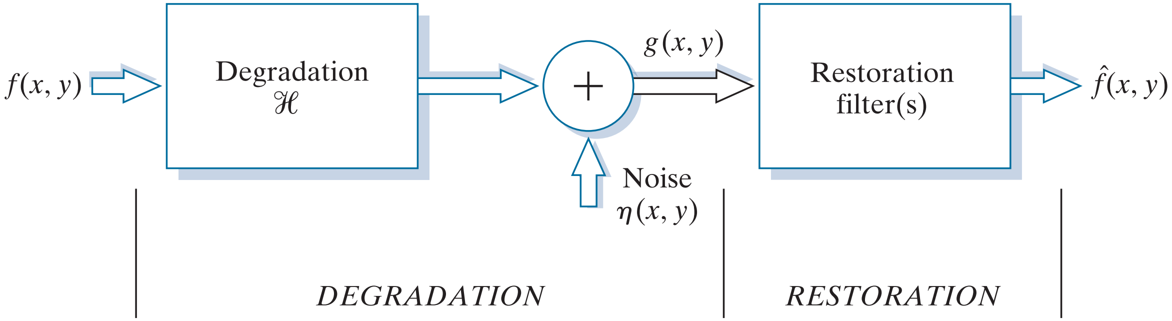
- Any image acquired by sensor is likely to be degraded
  - Reasons:
    - Sensor noise (because of quantization, sampling etc.)
    - Blur due to camera misfocus, relative object-camera motion
    - Random atmosphere turbulence (due to random variation in the refractive index of the medium between object and the imaging system

- Image could be degraded due to aging

Image Enhancement Vs Restoration

- Both Enhancement and Restoration improve an image in some predefined sense
- Image Enhancement is **Subjective**
  - Deals with improving the appearance : by point processing, contrast stretching, histogram equalization etc
- Image Restoration is **Objective**
  - Tries to recover original image from degraded image, with prior knowledge of degradation process
  - Models degradation and applies the inverse process to recover original image
- What if its not possible to model degradation function?
  - **Blind restoration technique attempts restoration without degradation function**

Degradation / Restoration Model



- Spatial Domain: g(x,y) = h(x,y)*f(x,y) + η(x,y)

- Frequency Domain: G(u,v) = H(u,v).F(u,v) + N(u,v)

Degradation / Restoration Model

- f(x,y) is degraded by a degradation function “H”. The output of this degradation function gets added to additive noise η(x,y)
- This gives degraded and noisy image g(x,y), from which we want to restore f(x,y)
  - We perform filtering operation to recover f(x,y) from g(x,y)
  - The restoration filter is derived using the knowledge of degradation function “H”.
  - The output of restoration filter is the restored image $\hat{f}(x,y)$ which is approximation of original image f(x,y)

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

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

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

- Operations Involved:
  - Image Denoising
  - Inverse Filtering

Image Denoising

- For denoising first we assume that H is an identity operator (H(u,v)=1) and all degradation is due to the noise

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

$$G(u,v) = F(u,v) + N(u,v)$$

- Restoration:

$$\hat{F}(u,v) = G(u,v) - N(u,v)$$

$$\hat{F}(u,v) = G(u,v) - N(u,v)$$

- In order to apply restoration process to “G” we need to estimate “N”

- Estimation of N is possible if characteristics of noise is known and noise model can be obtained

Characteristics of Noise

- Spectral characteristics of noise:
  - Spectrum of noise is constant. Noise contains nearly all frequencies in the visible spectrum in equal proportions, "White Noise"
- Spatial characteristics of noise:
  - Noise is independent of spatial coordinates. It is uncorrelated with image
  - Spatial noise descriptor is the statistical behaviour of the noise intensity values.
  - Noise intensity is considered as a random variable characterized by a certain **probability density function (pdf)**

Noise Models

- Noise is modeled by a known Probability Density Function (pdf)
- Two categories:
  - Noise which is independent of spatial location: Gaussian, Rayleigh, Erlang (gamma), exponential & uniform noise
  - Noise which is dependent on spatial location: Periodic noise

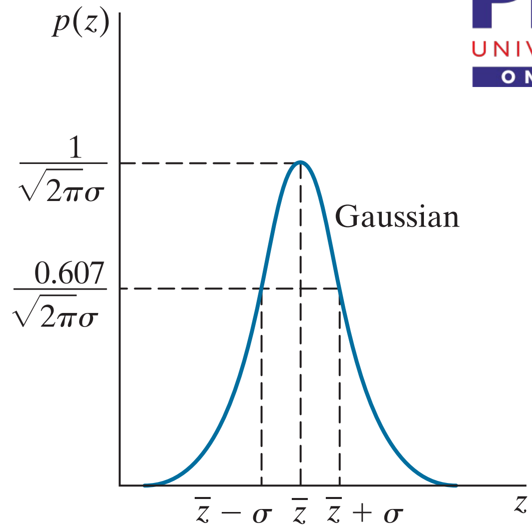
Common Noise pdf found in Image Processing Applications

- **Gaussian Noise:** (Normal Noise model)
  - Most frequently occurring noise is additive Gaussian

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

Where z= intensity/gray level value

- Examples:
  - Electric circuit noise
  - Sensor noise due to illumination or high temperature



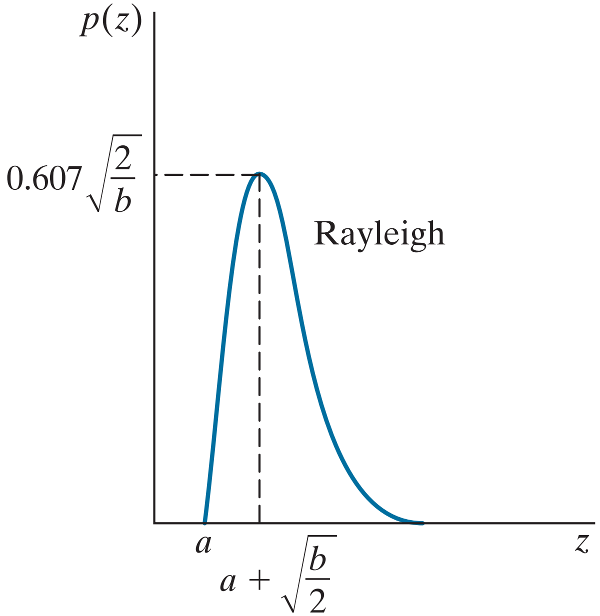
- 70% of values are in μ-σ and μ+σ
- 95% of values are in μ-2σ

and μ+2σ

Rayleigh Noise

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

$$\bar{z} = a + \sqrt{\pi b/4}; \quad \sigma^2 = \frac{b(4-\pi)}{4}$$

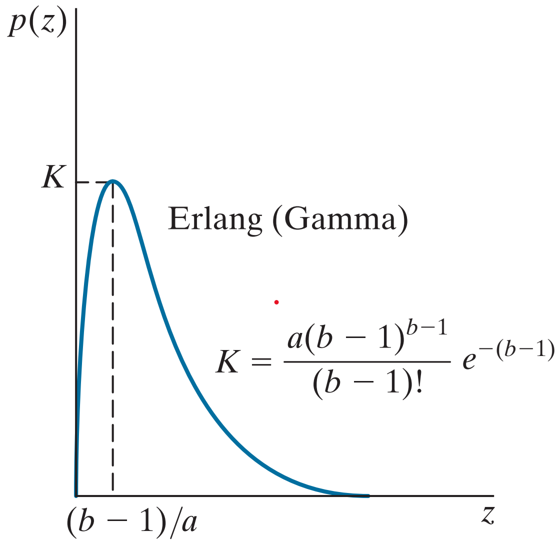


- pdf doesn't start from origin and is not symmetrical w.r.t centre of curve
- Thus useful for approximating skewed (non uniform histogram (in range imaging))

Erlang (Gamma) Noise

$$p(z) = \begin{cases} \dfrac{a^b z^{b-1}}{(b-1)!} e^{-az}, & z \geq 0 \\ 0, & z < 0 \end{cases} ; \quad a > 0; \quad b \text{ **positive integer**}$$

$$\bar{z} = \frac{b}{a}; \quad \sigma^2 = \frac{b}{a^2}$$



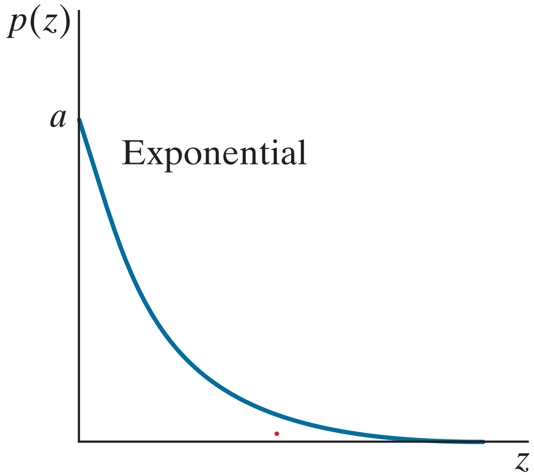
- Where a and b are positive integers
- Mean density is given by b/a
- Variance $\sigma^2 = b/a^2$

Exponential Noise

- PDF is given by

$$p(z) = \begin{cases} a\,e^{-az}, & z \geq 0 \\ 0, & z < 0 \end{cases} ; \quad a > 0$$

$$\bar{z} = \frac{1}{a}; \quad \sigma^2 = \frac{1}{a^2}$$



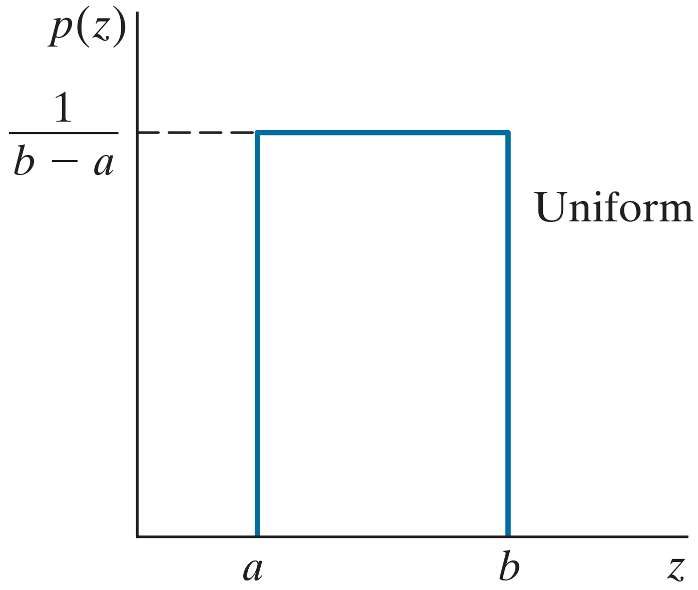
- PDF of Exponential noise = PDF of Erlang noise when b=1

Uniform Noise

- Specified by

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

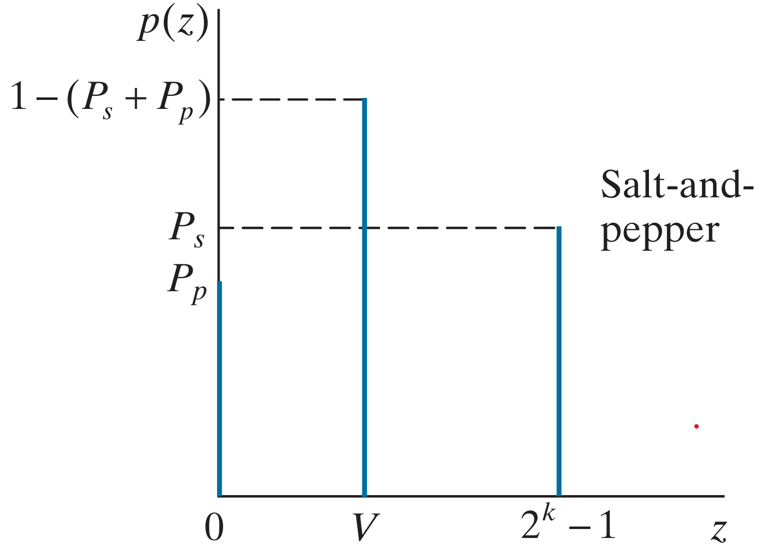
$$\bar{z} = \frac{a+b}{2}; \quad \sigma^2 = \frac{(b-a)^2}{12}$$



Impulse (Salt & Pepper) Noise

- Specified by

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



Features of Salt & Pepper Noise

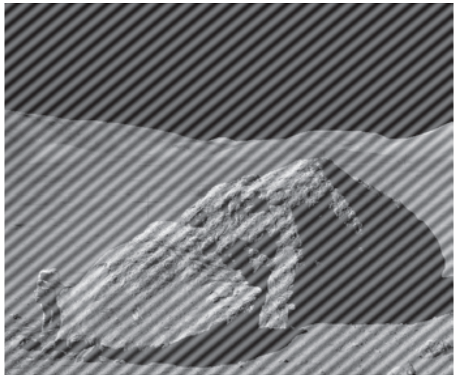
- Generally a and b values are saturated(very high or very low), resulting in positive impulse being white(salt) and negative impulses being black (pepper)
- If $p_a = 0$, only p_b exists: salt noise (only white dots are visible as noise)
- If $p_b = 0$, only p_a exists: Pepper noise (only black dots are visible as noise)
- If $P_a = 0$ or $P_b = 0$: Unipolar Noise
- If b > a, “b” will appear as a light dot on the image and “a” will appear as dark dot: Bipolar noise
- Impulse noise occurs when quick transitions happen.(such as faulty switching)

Periodic Noise

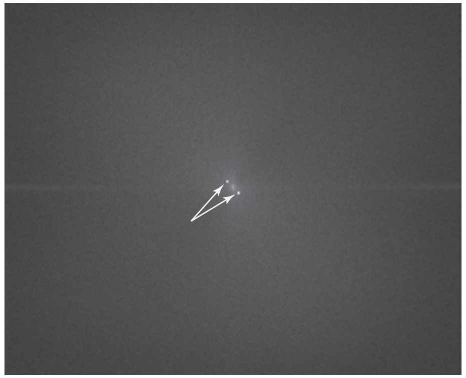
- **This is the only type of spatially dependent noise**
- Arises during image acquisition,
- Electrical or electro mechanical interference may cause such type of periodic noise
- **Can be reduced significantly via frequency domain filtering**

Periodic Noise

- Consider the following image corrupted by additive (spatial) sinusoidal noise.



- w.k.t he Fourier transform of a pure sinusoid is a pair of conjugate impulses located at the conjugate frequencies of the sine wave
- Thus, if the amplitude of a sine wave in the spatial domain is strong enough, we would expect to see in the spectrum of the image as a pair of impulses for each sine wave in the image



Spectrum showing two conjugate impulses caused by the sine wave.

Eliminating or reducing these impulses in the frequency domain will eliminate or reduce the sinusoidal noise in the spatial domain.

Next Session

- Estimation of noise parameters
- Restoration in the presence of Noise only

THANK YOU

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