University of Massachusetts Amherst

Digital Image Processing ECE 566

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Last Lecture

Convolution and Correlation

Separable Kernels

Smoothing Filters

Spatial Sharpening

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Convolution and Correlation

Separable Kernels

Smoothing Filters

Spatial Sharpening

Unsharp Masking

Image Restoration

Noise Model

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Unsharp Masking

- ✓ Blur/Smooth the original image
- ✓ Subtract the blurred image from the original

$$f(x,y) - \overline{f(x,y)}$$

- ✓ Add the resulting mask to the original

$$g(x,y) = f(x,y) + k(f(x,y) - \overline{f(x,y)})$$

$k = 1$ unsharp masking
$k > 1$ highboost filtering

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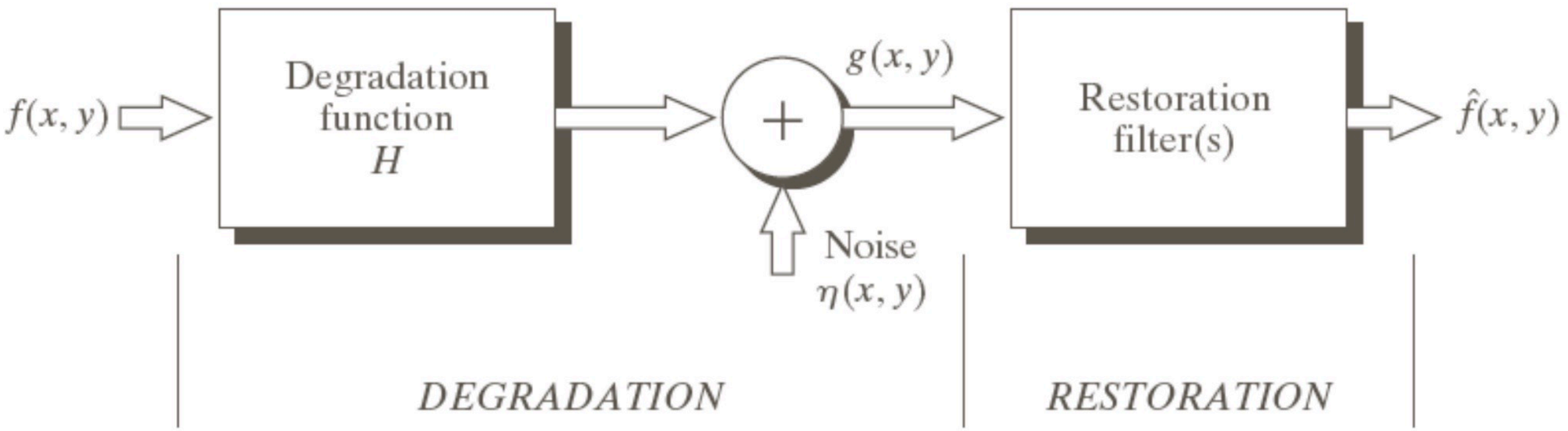
- ✓ Frequency-domain restoration

  Used for degradations such as image blur

Image Restoration

- ✓ What is noise (in the context of image processing) and how can it be modeled?
- ✓ What are the main types of noise that may affect an image?
- ✓ What are the possible solutions?

Model of Image Degradation/Restoration



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

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

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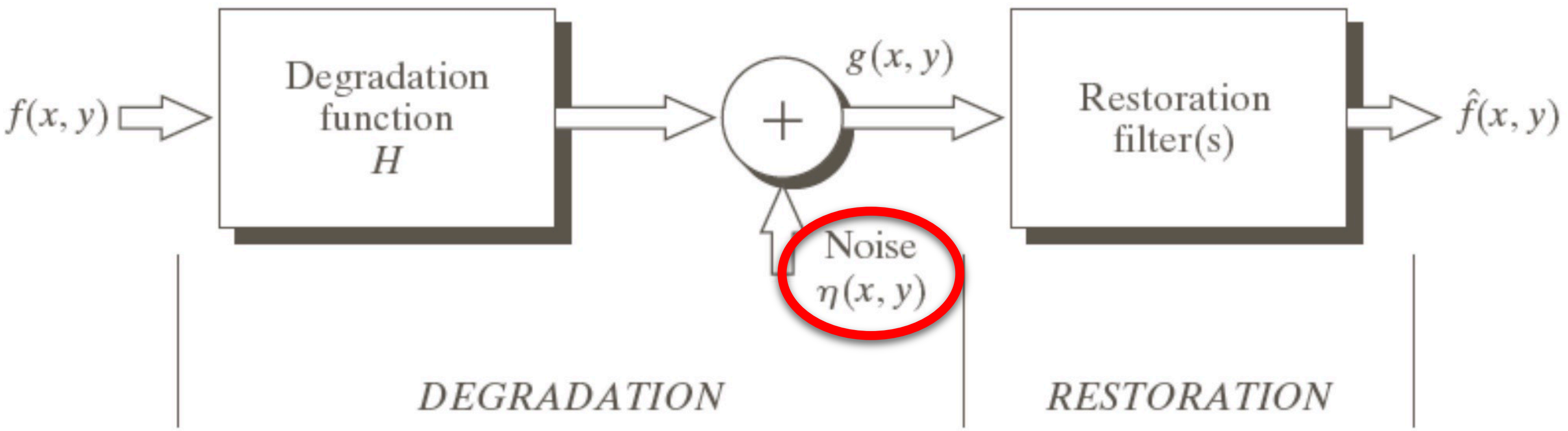

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Noise Sources

✓ Image acquisition (digitization)

1. Environmental conditions
2. Quality of sensors

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✓ Image transmission

Interference by lightening or other atmospheric disturbance

Noise Model Assumption

- ✓ Noise is independent of image coordinates
- ✓ Noise is not correlated with the image; no correlation between pixel values and noise components

Noise Models

- ✓ Spatial noise models are based on the statistical behavior of gray-level values

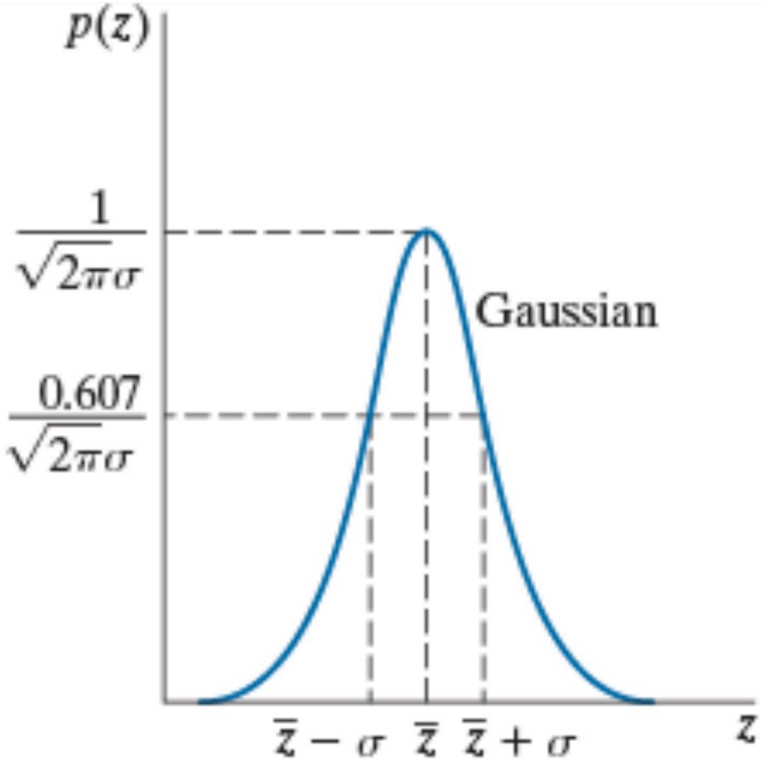
- ✓ Gray-level values are considered as random variables characterized by a probability density function (PDF)

- ✓ Gaussian (normal)
- ✓ Impulse (salt-and-pepper)
- ✓ Uniform
- ✓ Rayleigh
- ✓ Gamma (Erlang)
- ✓ Exponential

Noise Models: Gaussian Noise

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

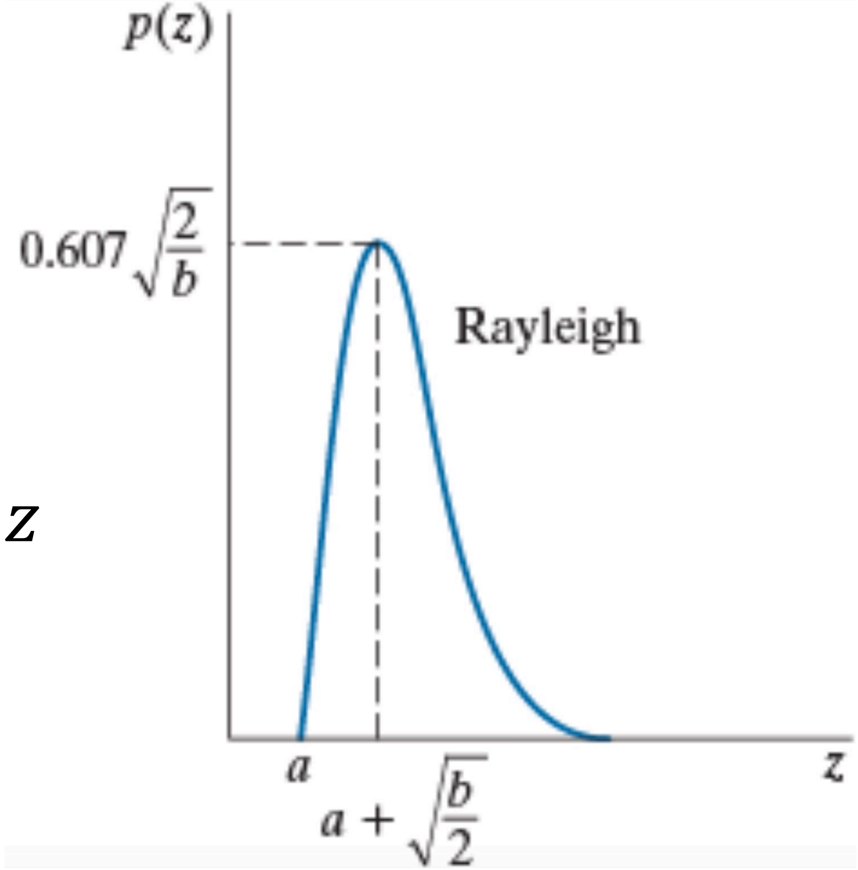
- ✓ z: gray level
- ✓ μ: mean of random variable z
- ✓ σ^2: variance of z



Noise Models: Rayleigh Noise

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

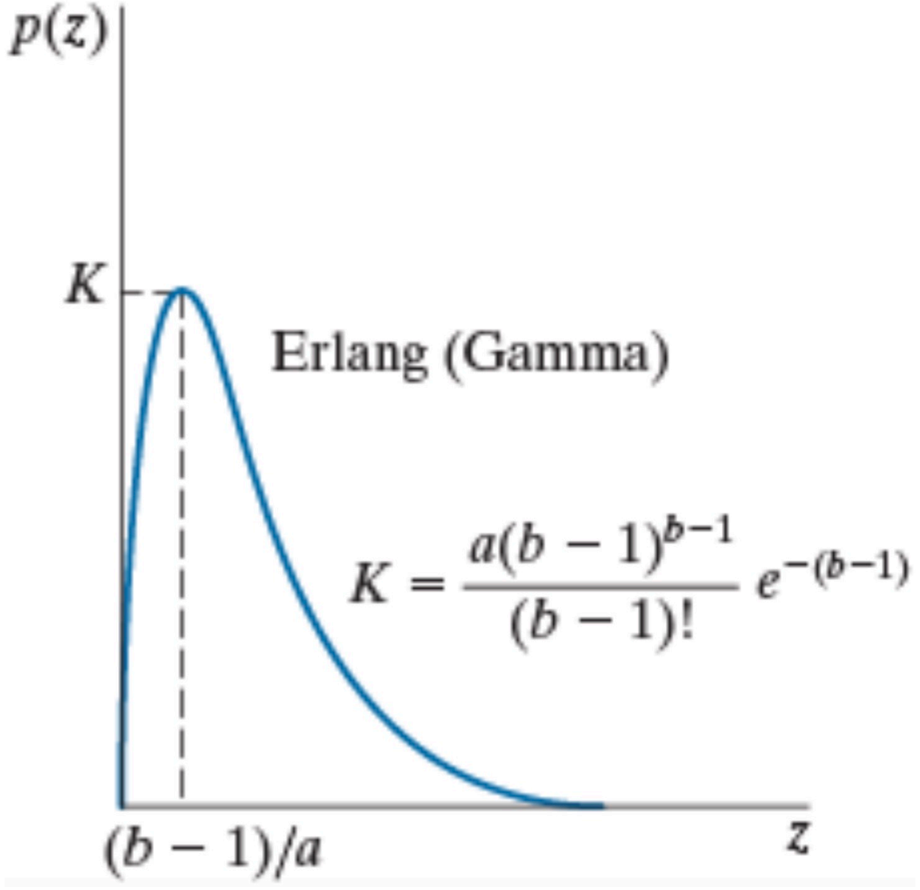
- ✓ z: gray level
- ✓ $\mu = a + \sqrt{\frac{\pi b}{4}}$: mean of random variable z
- ✓ $\sigma^2 = \frac{b(4-\pi)}{4}$: variance of z



Noise Models: Gamma (Erlang) Noise

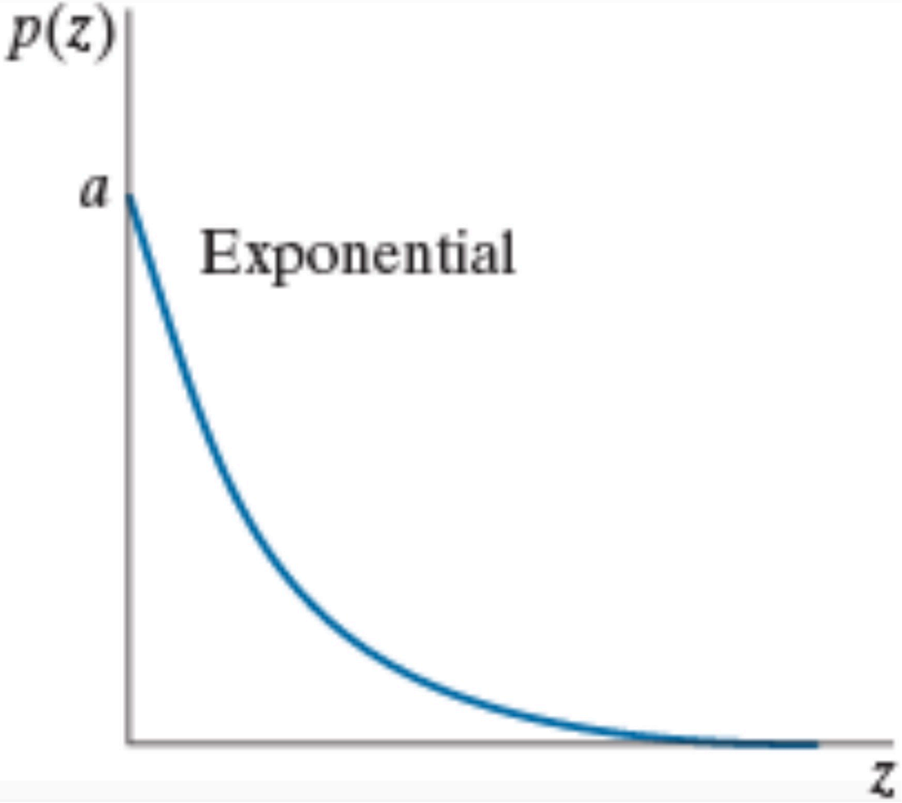
$$p(z) = \begin{cases} \dfrac{a^b z^{b-1}}{(b-1)!} e^{-az} & z \geq 0 \\ 0 & z < 0 \end{cases}$$

- ✓ z: gray level
- ✓ $\mu = \frac{b}{a}$: mean of random variable z
- ✓ $\sigma^2 = \frac{b}{a^2}$: variance of z
- ✓ $a > 0, b$ is a positive integer number



Noise Models: Exponential Noise

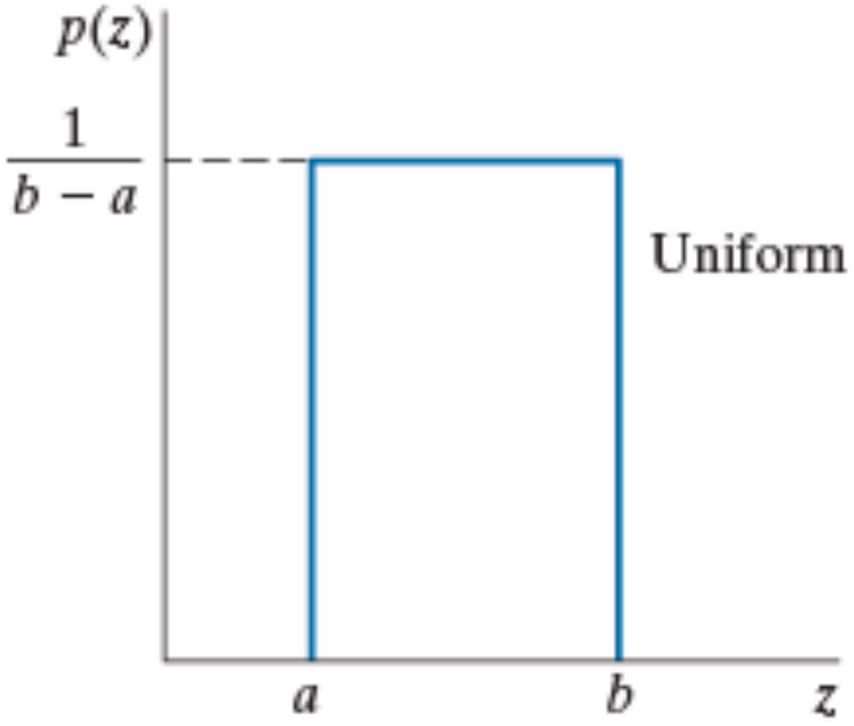
$$p(z) = \begin{cases} ae^{-az} & z \geq 0 \\ 0 & z < 0 \end{cases}$$



- ✓ It is an Erlang PDF with $b = 1$
- ✓ z: gray level
- ✓ $\mu = \frac{1}{a}$: mean of random variable z
- ✓ $\sigma^2 = \frac{1}{a^2}$: variance of z
- ✓ $a > 0, b$=1 is a positive integer number

Noise Models: Uniform Noise

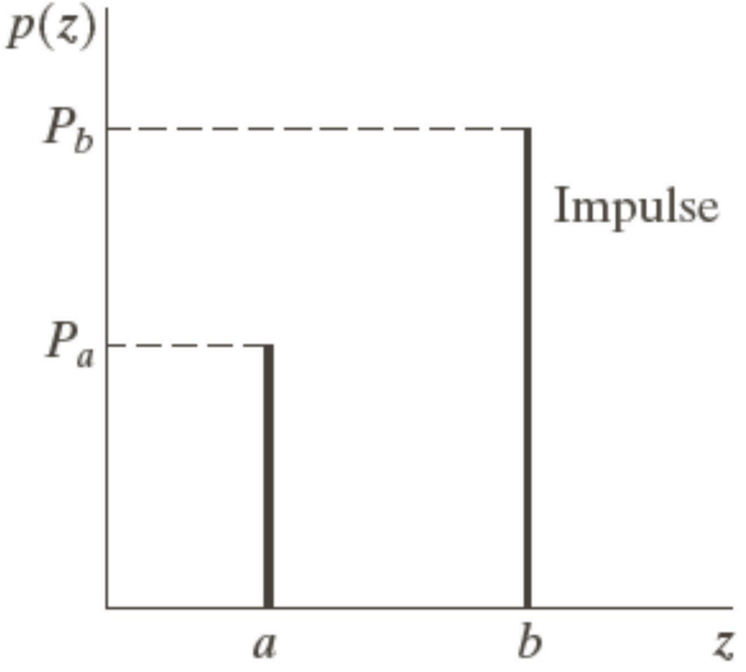
$$p(z) = \begin{cases} \dfrac{1}{b-a} & a \leq z \leq b \\ 0 & \text{otherwise} \end{cases}$$



- ✓ z: gray level
- ✓ $\mu = \frac{a+b}{2}$: mean of random variable z
- ✓ $\sigma^2 = \frac{(b-a)^2}{12}$: variance of z

Noise Models: Impulse Noise (salt and pepper)

$$p(z) = \begin{cases} P_b & z = 2^k - 1 \\ P_a & z = 0 \\ 1 - (P_a + P_b) & z = V \end{cases}$$

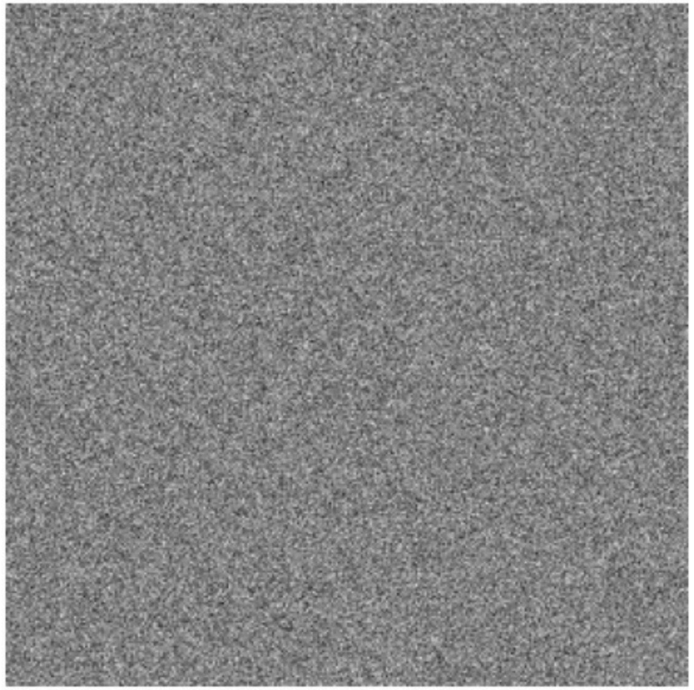


- ✓ $0 < V < 2^k - 1$
- ✓ z: gray level
- ✓ $\mu = (2^k - 1)\, P_b + (1 - (P_a + P_b))$: mean of random variable z
- ✓ $\sigma^2 = \mu^2 P_a + (K - \mu^2)\big(1 - (P_a + P_b)\big) + (2^k - 1)^2 P_b$: variance of z
- ✓ Normally, $a = 0$ (black) and $b = 255$ (white)
- ✓ Unipolar impulse noise: $P_a = 0$ or $P_b = 0$
- ✓ Bipolar impulse noise: $P_a \approx P_b \neq 0$

Noise Models: Example

Original

Gaussian Noise



Combined

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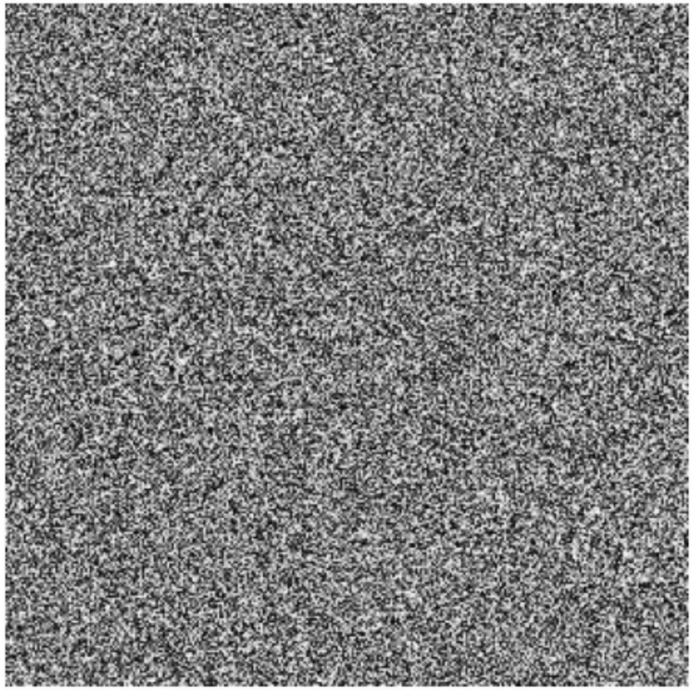
Noise Models: Example

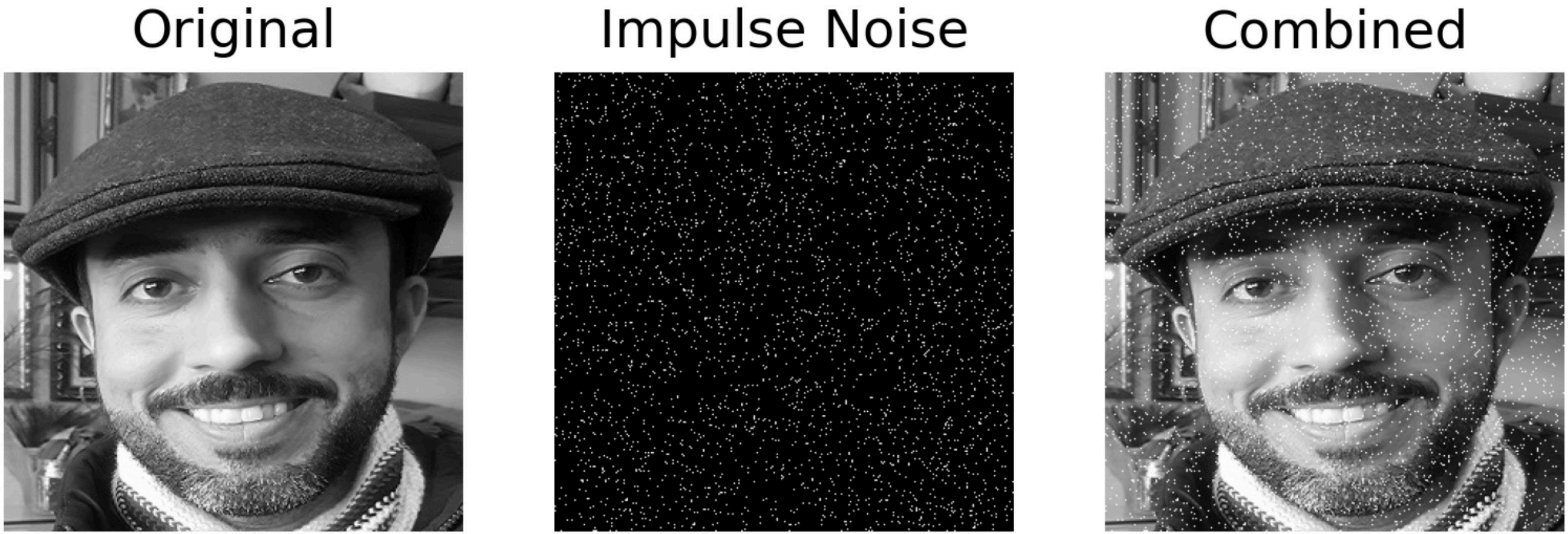
Original

Uniform Noise

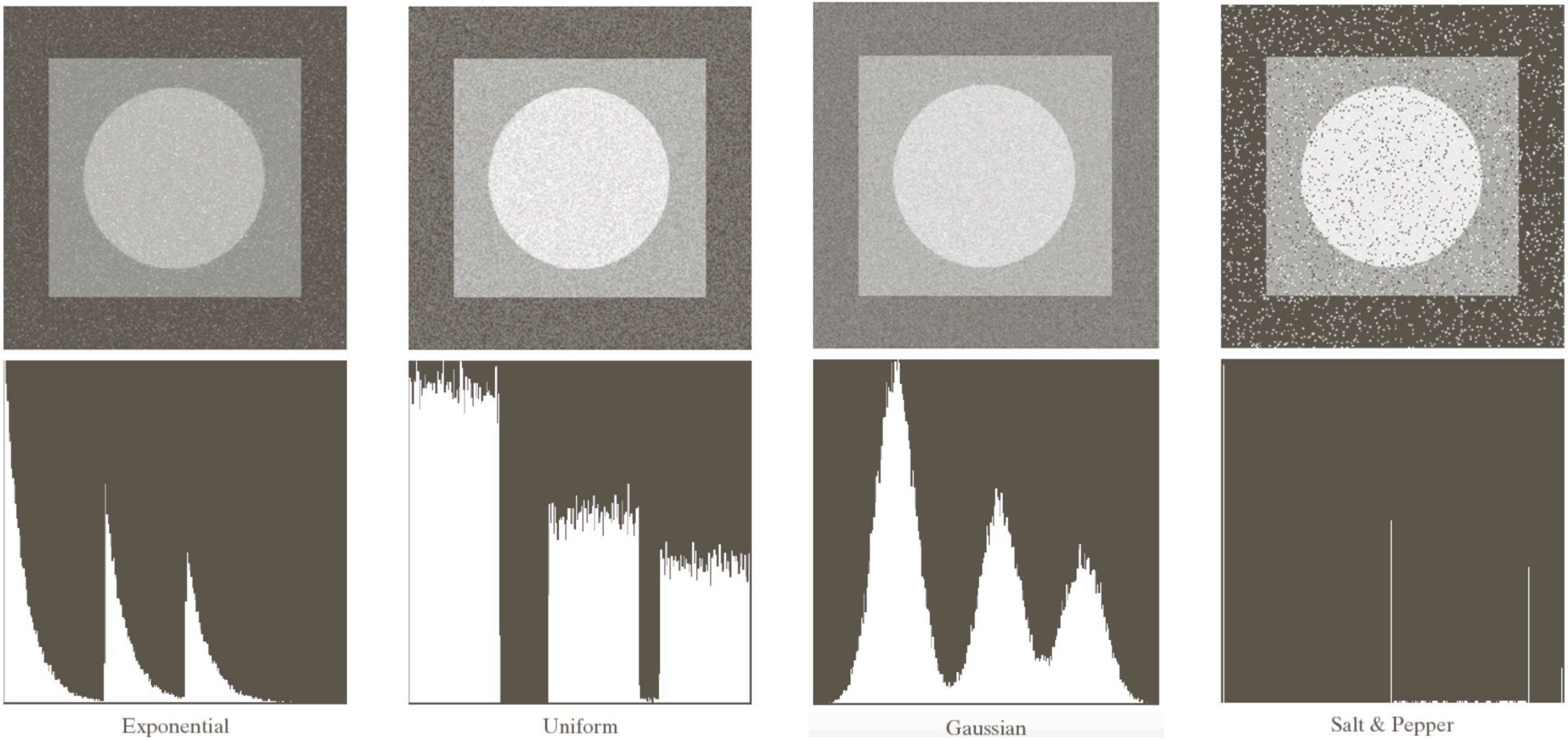


Combined

Noise Models: Example



Noise Models: distribution of gray-level




QUIZ
TIME