CSC 4227 Digital Image Processing

Lecture 18 – Image Restoration : Noise Removal

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Contents

In this lecture we will look at image restoration techniques used for noise removal

- What is image restoration?
- Noise and images
- Noise models
- Noise removal using spatial domain filtering
- Periodic noise
- Noise removal using frequency domain filtering

What is Image Restoration?

- Image restoration attempts to restore images that have been degraded
  - ✓ Identify the degradation process and attempt to reverse it.
  - ✓ Almost Similar to image enhancement, but more objective.

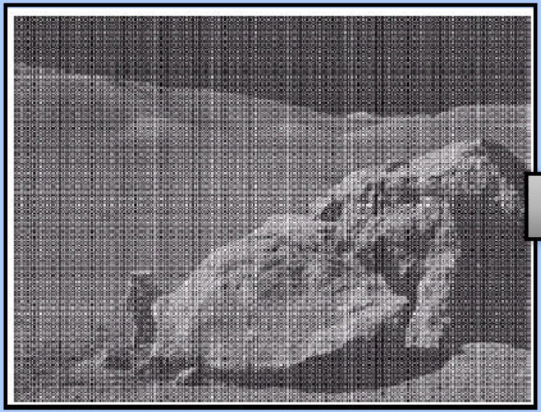


Fig: Degraded image

Fig: Restored image

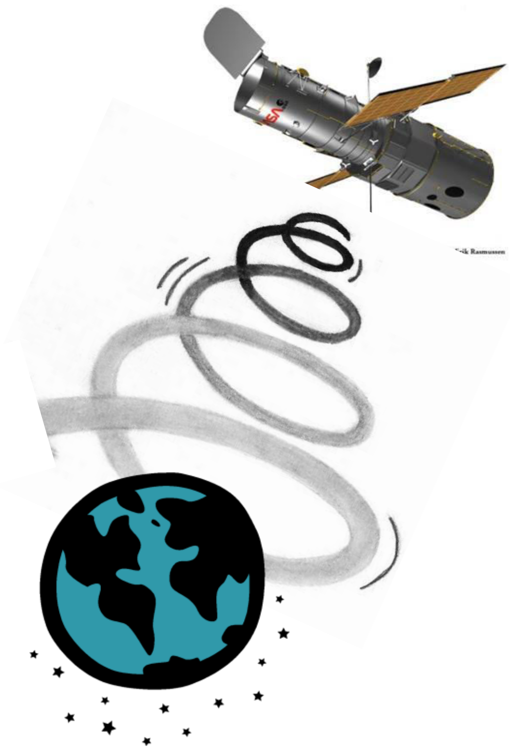
Image enhancement vs. Image Restoration

- Image restoration assumes a degradation model that is known or can be estimated.
- Original content and quality does not mean Good looking or appearance.
- Image Enhancement is subjective, where as image restoration is objective process.
- Image restoration try to recover original image from degraded with prior knowledge of degradation process.
- Restoration involves modeling of degradation and applying the inverse process in order to recover the original image.
- Although the restore image is not the original image, its approximation of actual image.

Noise and Images

The sources of noise in digital images arise during image acquisition (digitization) and transmission

- Imaging **sensors** can be affected by ambient conditions
- Interference can be added to an image **during transmission**



Noise Model

We can consider a noisy image to be modelled as follows:

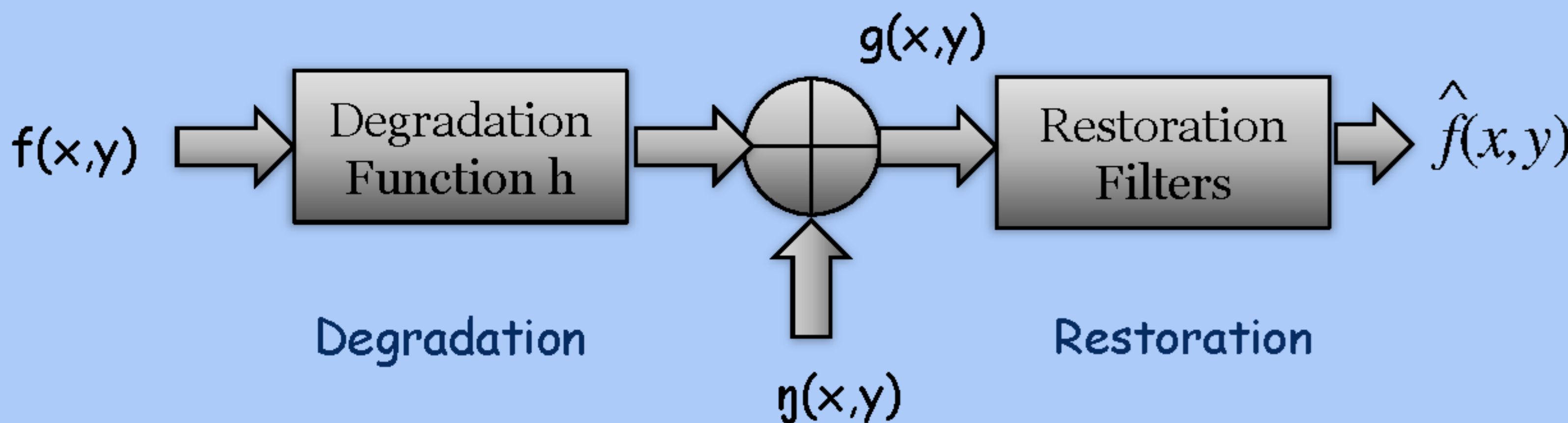
$$g(x, y) = f(x, y) + \eta(x, y)$$

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

If we can estimate the model the noise in an image is based on this will help us to figure out how to restore the image

Degradation Model?

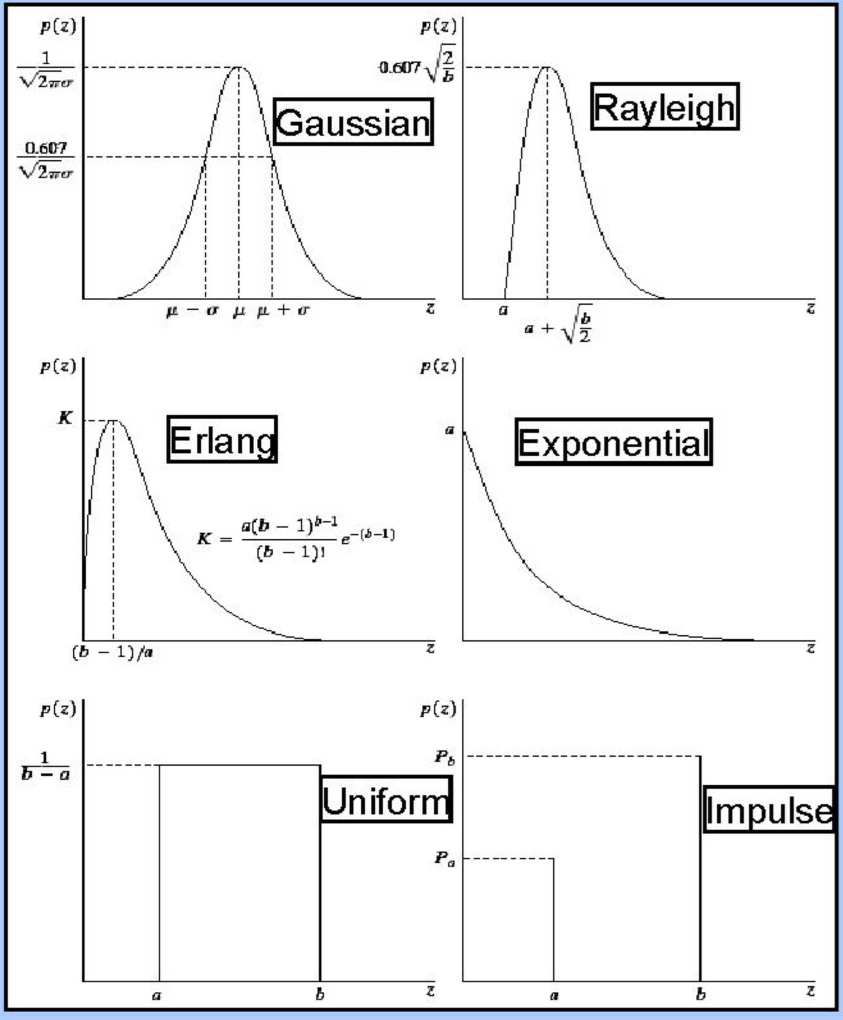
- **Objective**: To restore a degraded/distorted image to its original content and quality.



- **Spatial Domain**: $g(x,y)=h(x,y)*f(x,y)+\eta(x,y)$
- **Frequency Domain**: $G(u,v)=H(u,v)F(u,v)+\eta(u,v)$
- **Matrix**: $G=HF+\eta$

Noise Models and Their PDF

- Different models for the image noise term η(x, y)
  - ✓ Gaussian
    - Most common model
  - ✓ Rayleigh
  - ✓ Erlang or Gamma
  - ✓ Exponential
  - ✓ Uniform
  - ✓ Impulse
    - Salt and pepper noise



Noise Models

Noise cannot be predicted but can be approximately described in statistical way using the probability density function (PDF)

Gaussian noise:

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

Rayleigh noise

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

Erlang (Gamma) noise

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

Noise Models (cont.)

Exponential noise

$$p(z) = ae^{-az}$$

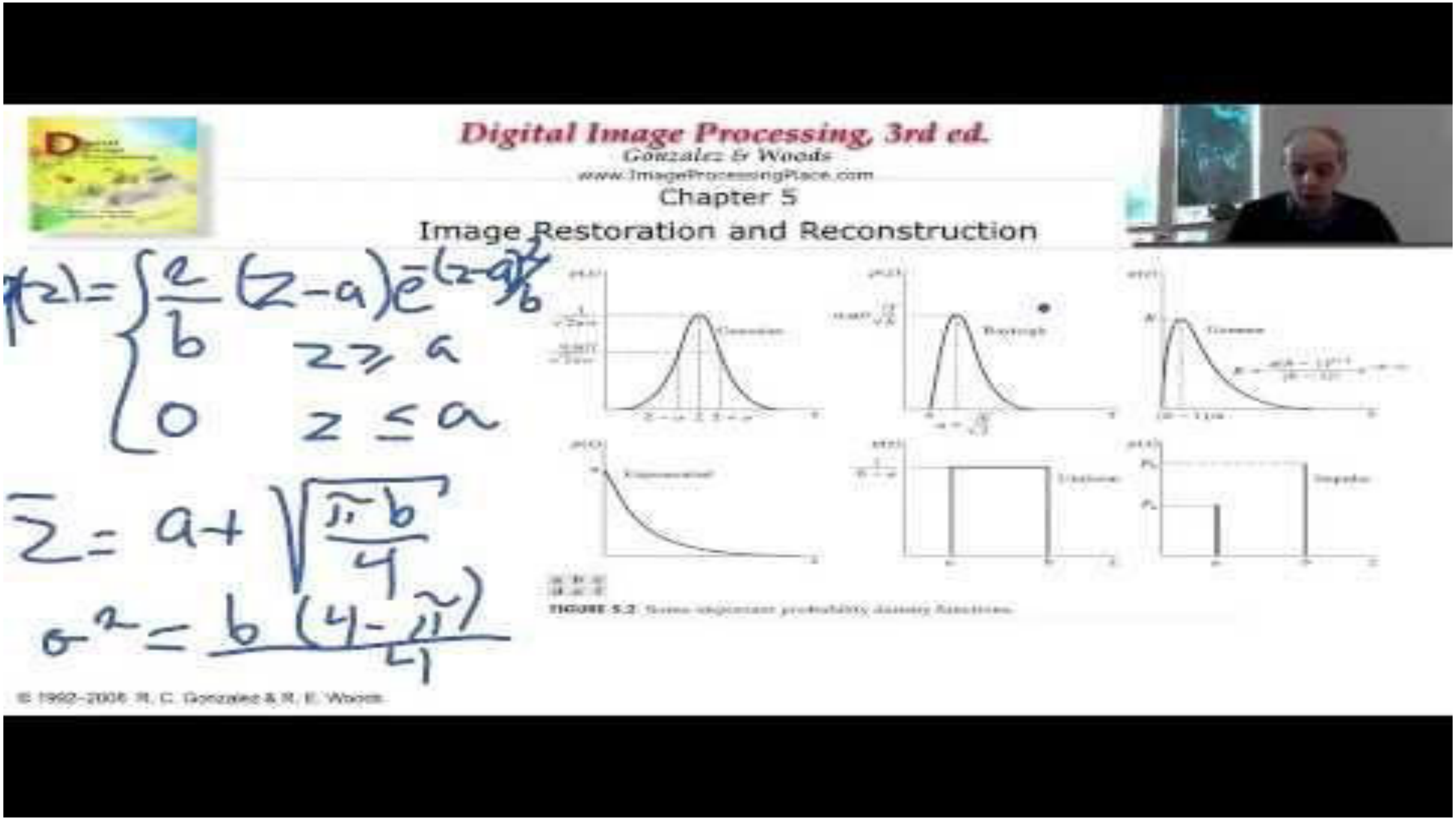
Uniform noise

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

Impulse (salt & pepper) noise

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

Noise Types (optional to watch)



https://www.youtube.com/watch?v=vZNyZgdEhgQ

Noise Models Effects

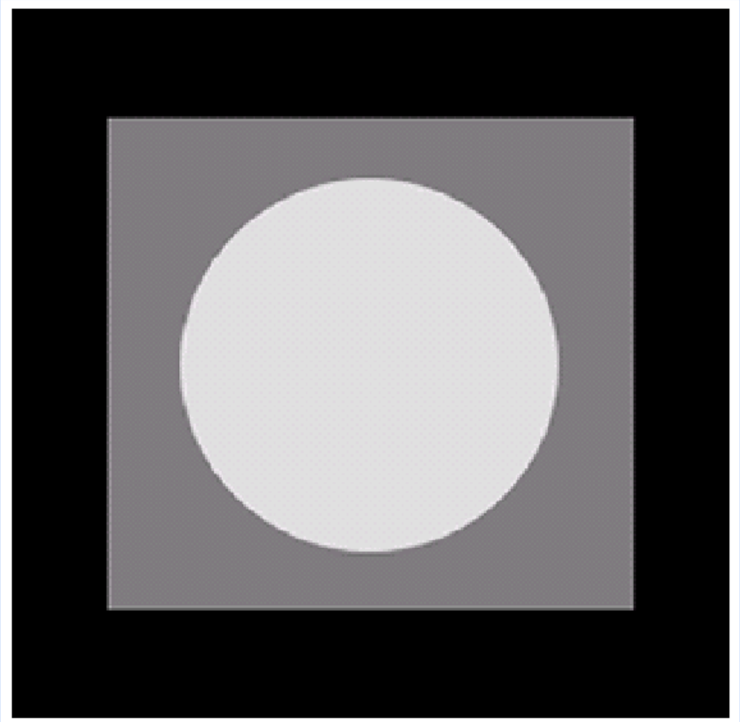
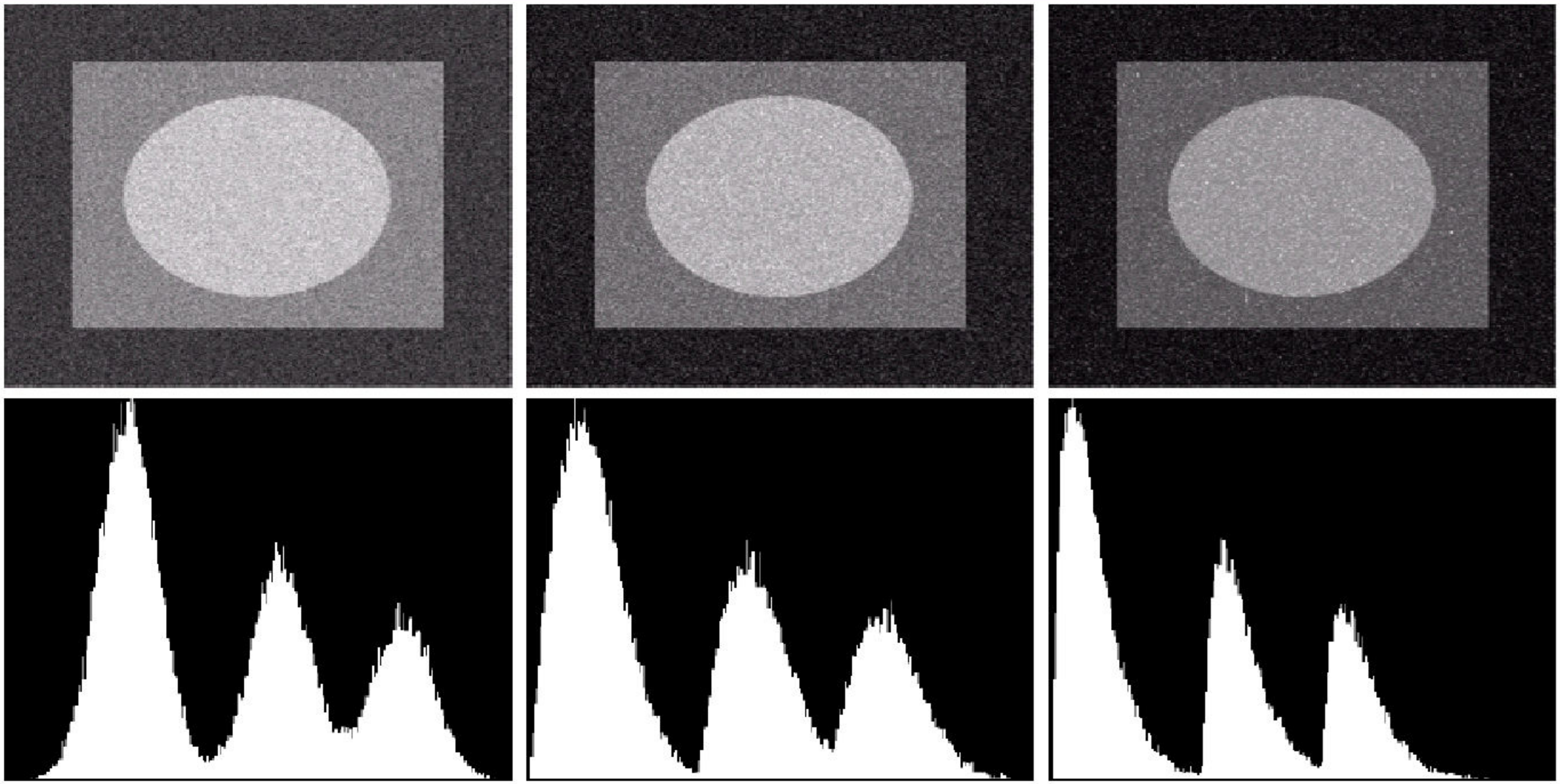


Fig: Original Image

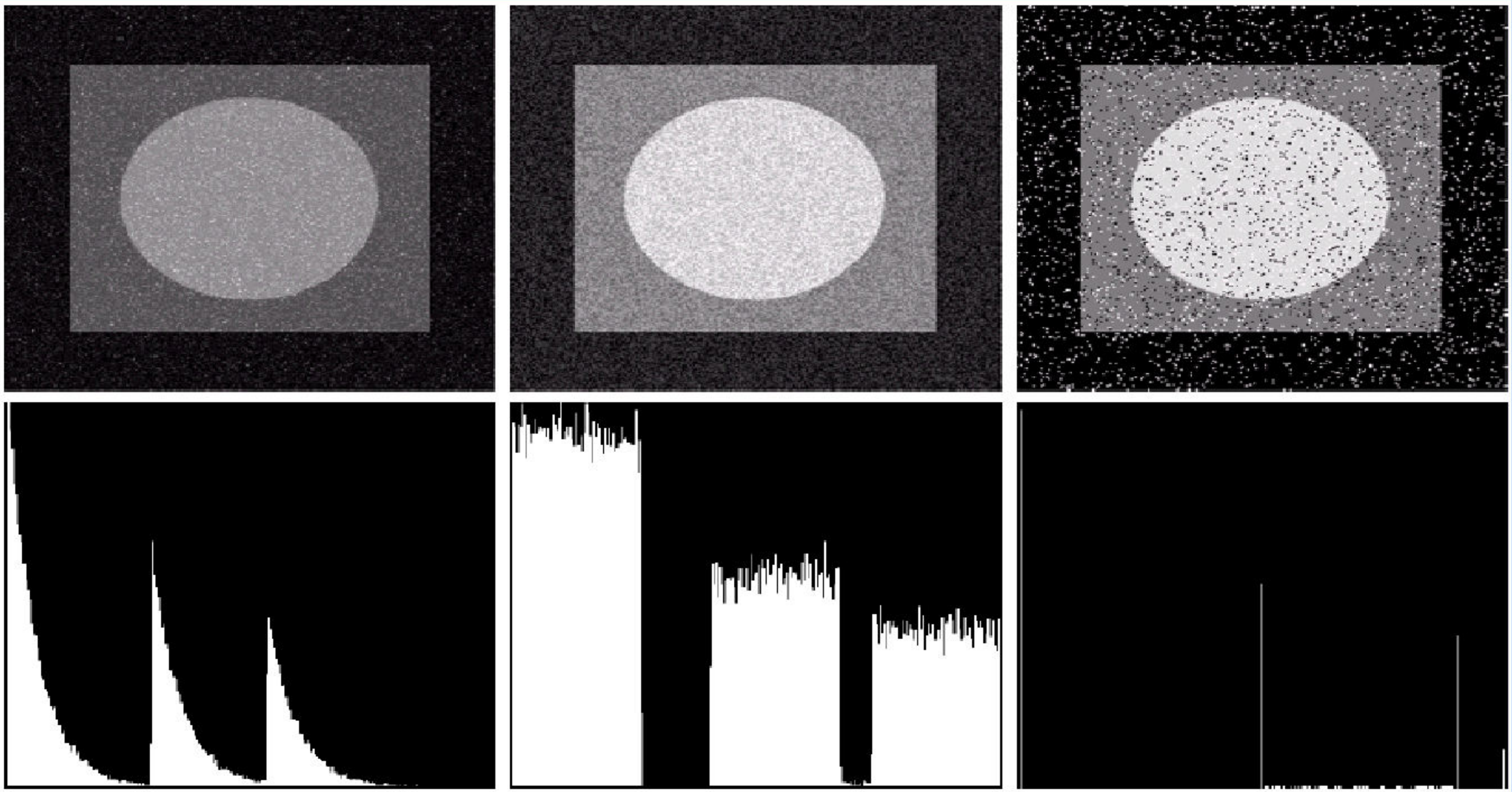
Fig: Original Image histogram

Noise Models Effects contd1...



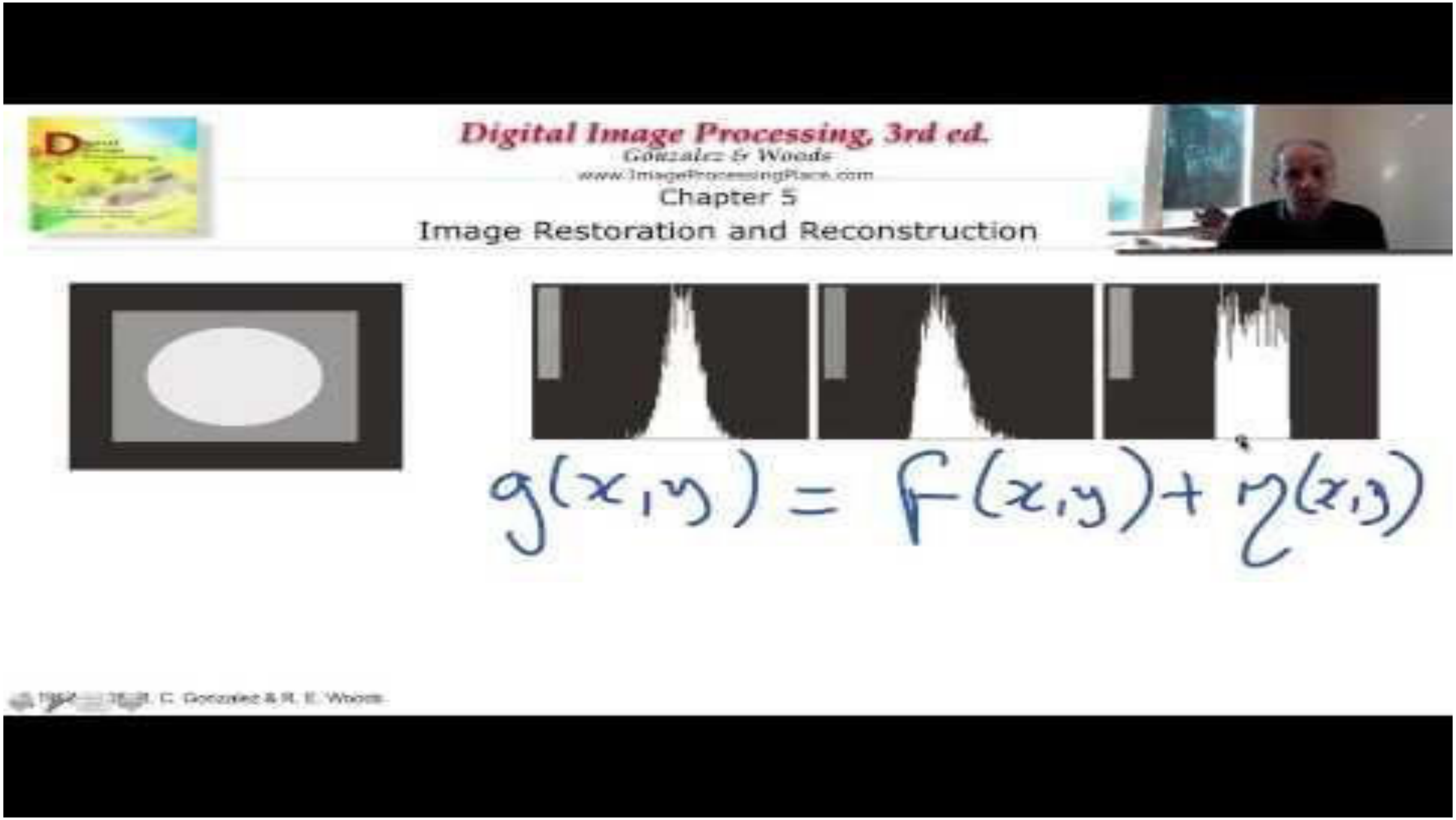
Gaussian Rayleigh Gamma

Noise Models Effects contd2...



Exponential Uniform Salt & Pepper

Estimating noise



https://www.youtube.com/watch?v=CIa60r2E2VI

Restoration Techniques.

- Inverse Filtering.
- Minimum Mean Squares Errors.
  - ✓ Weiner Filtering.
- Constrained Least Square Filter.
- Non linear filtering
- Advanced Restoration Technique.

Filter used for Restoration Process

- Mean filters
  - Arithmetic mean filter
  - Geometric mean filter
  - Harmonic mean filter
  - Contra-harmonic mean filter
- Order statistics filters
  - Median filter
  - Max and min filters
  - Mid-point filter
  - alpha-trimmed filters
- Adaptive filters
  - Adaptive local noise reduction filter.
  - Adaptive median filter

Filtering to Remove Noise-AMF

- Use spatial filters of different kinds to remove different kinds of noise
- Arithmetic Mean :

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t)$$

- This is implemented as the simple smoothing filter Blurs the image to remove noise.

$^1/_9$	$^1/_9$	$^1/_9$
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Filtering to Remove Noise-GMF

- **Geometric Mean**:

$$\hat{f}(x,y) = \left[\prod_{(s,t)\in S_{xy}} g(s,t) \right]^{\frac{1}{mn}}$$

- Achieves similar smoothing to the arithmetic mean, but tends to lose less image detail.

Filtering to Remove Noise-HMF

- **Harmonic Mean:**

$$\hat{f}(x,y) = \frac{mn}{\displaystyle\sum_{(s,t)\in S_{xy}} \frac{1}{g(s,t)}}$$

- Works well for salt noise, but fails for pepper noise
- Satisfactory result in other kinds of noise such as Gaussian noise

Filtering to Remove Noise-CHMF

- **Contra-harmonic Mean:**

$$\hat{f}(x,y) = \frac{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q}}$$

- Q is the *order* of the filter and adjusting its value changes the filter's behaviour.
- Positive values of Q eliminate pepper noise.
- Negative values of Q eliminate salt noise.

Order Statistics Filters

- Spatial filters that are based on ordering the pixel values that make up the neighbourhood operated on by the filter
- Useful spatial filters include
  - Median filter.
  - Maximum and Minimum filter.
  - Midpoint filter.
  - Alpha trimmed mean filter.

Median Filter

- **Median Filter:**

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\}$$

- Excellent at noise removal, without the smoothing effects that can occur with other smoothing filters
- Best result for removing salt and pepper noise.

Maximum and Minimum Filter

- **Max Filter**:

$$\hat{f}(x, y) = \max_{(s,t)\in S_{xy}} \{g(s,t)\}$$

- **Min Filter**:

$$\hat{f}(x, y) = \min_{(s,t)\in S_{xy}} \{g(s,t)\}$$

- Max filter is good for pepper noise and min is good for salt noise

Midpoint Filter

- **Midpoint Filter:**

$$\hat{f}(x,y)=\frac{1}{2}\left[\max_{(s,t)\in S_{xy}}\{g(s,t)\}+\min_{(s,t)\in S_{xy}}\{g(s,t)\}\right]$$

- Good for random Gaussian and uniform noise

Alpha-Trimmed Mean Filter

- **Alpha-Trimmed Mean Filter:**

$$\hat{f}(x, y) = \frac{1}{mn-d} \sum_{(s,t)\in S_{xy}} g_r(s,t)$$

- Here deleted the *d/2* lowest and *d/2* highest grey levels, so $g_r(s, t)$ represents the remaining *mn - d* pixels

Answer these questions:

- Can we **detect** what type of **noise** is present in an **image**?
- How can we estimate **noise** from an **image**?
- How do you improve the quality of a **degraded image**?