Image Restoration & Reconstruction

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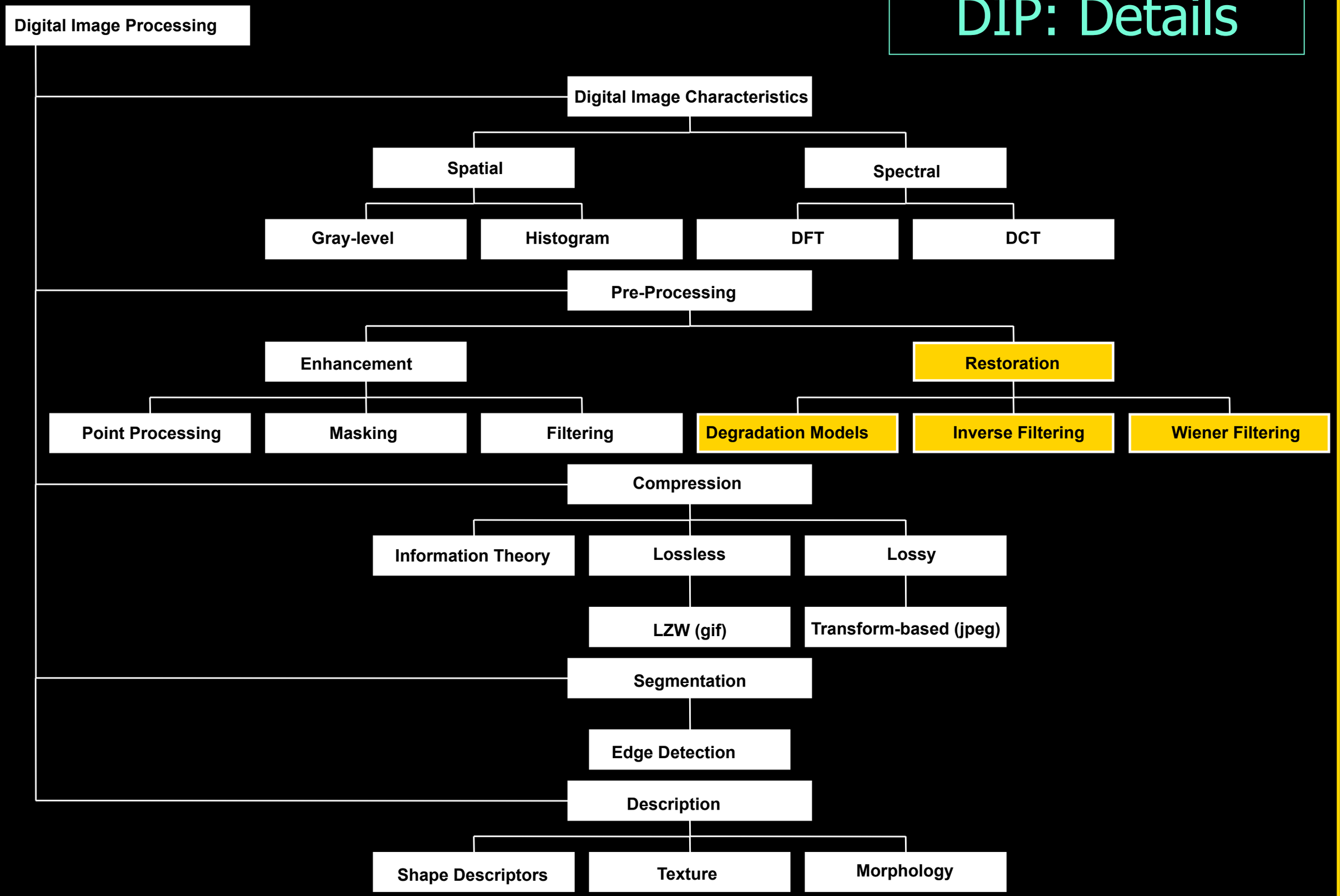
DIP: Details


Digital Image Processing
Digital Image Characteristics
Spatial
Spectral
Gray-level
Histogram
DFT
DCT
Pre-Processing
Enhancement
Restoration
Point Processing
Masking
Filtering
Degradation Models
Inverse Filtering
Wiener Filtering
Compression
Information Theory
Lossless
Lossy
LZW (gif)
Transform-based (jpeg)
Segmentation
Edge Detection
Description
Shape Descriptors
Texture
Morphology

Enhancement vs. Restoration

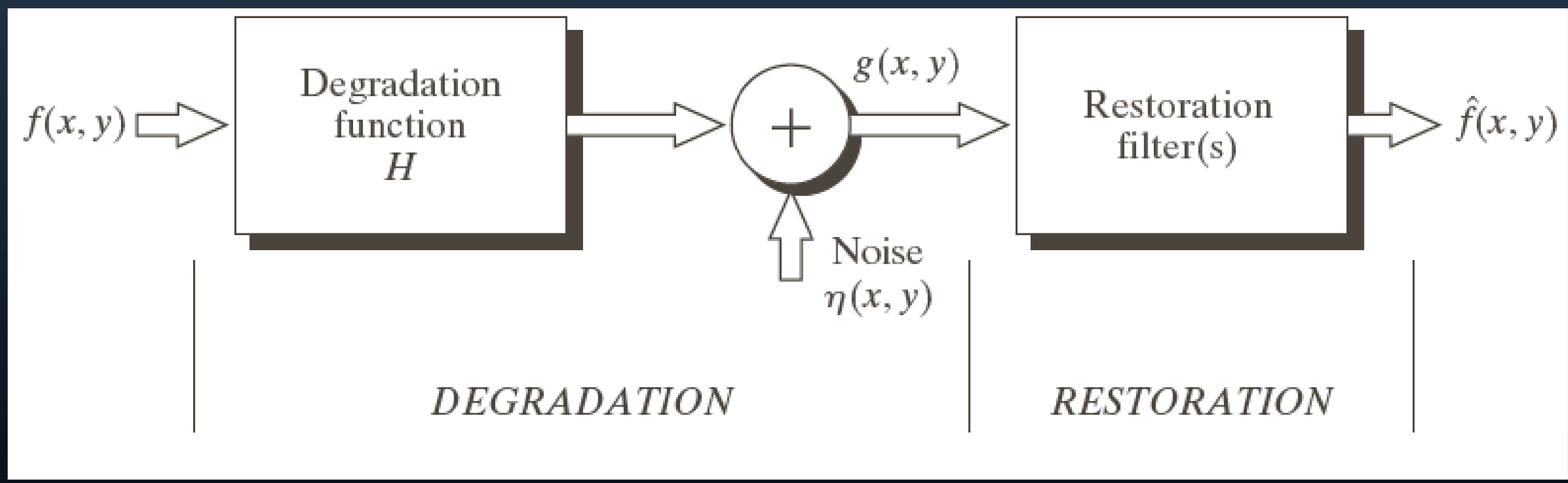
"Better" visual representation ⟷ **Remove effects of sensing environment**

Subjective ⟷ **Objective**

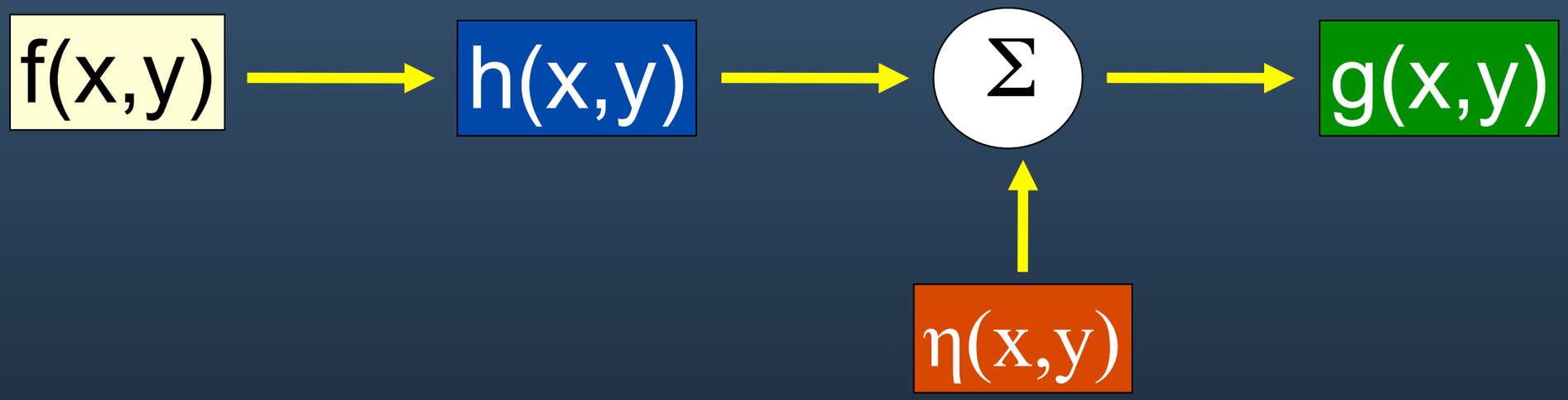
No quantitative measures ⟷ **Mathematical, model dependent quantitative measures**

Motivation & Model

- Motivation
  - Remove, or at least reduce, blur and noise in a digital image
  - Quantitative goal for spatial filtering



Degradation Model



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

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

Noise Models

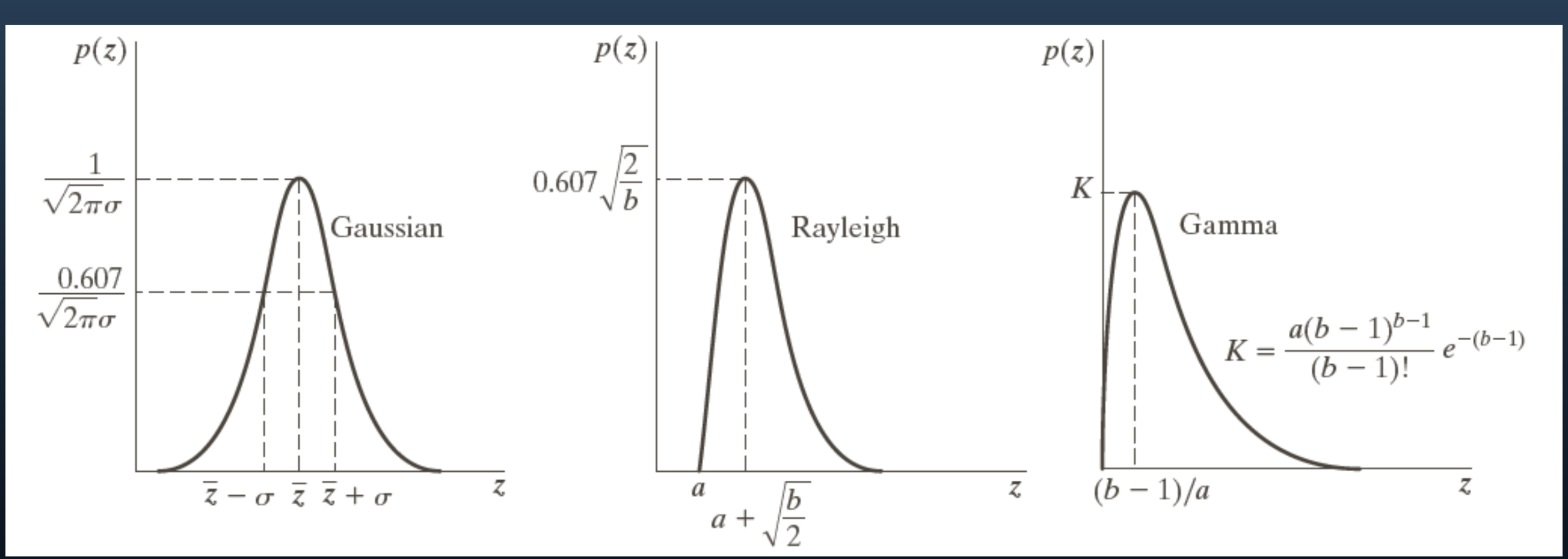
- White noise
  - The Fourier Spectrum is constant
- Random Noise
  - 假設與空間座標無關
- 以機率模式描述noise

Noise Probability Density Functions

Gaussian Noise

Rayleigh Noise

Gamma Noise

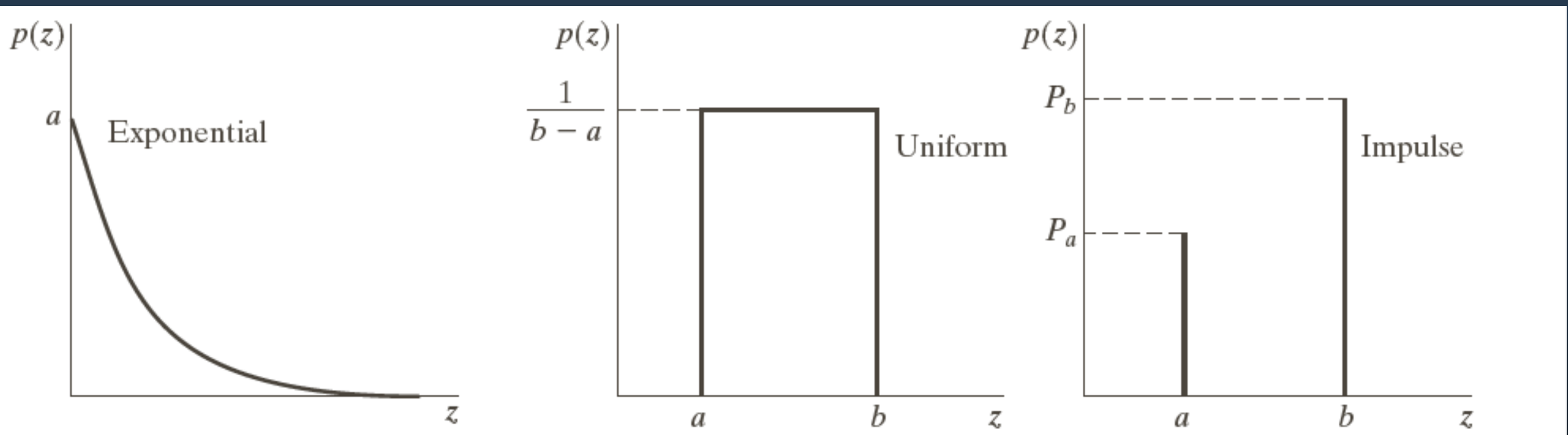


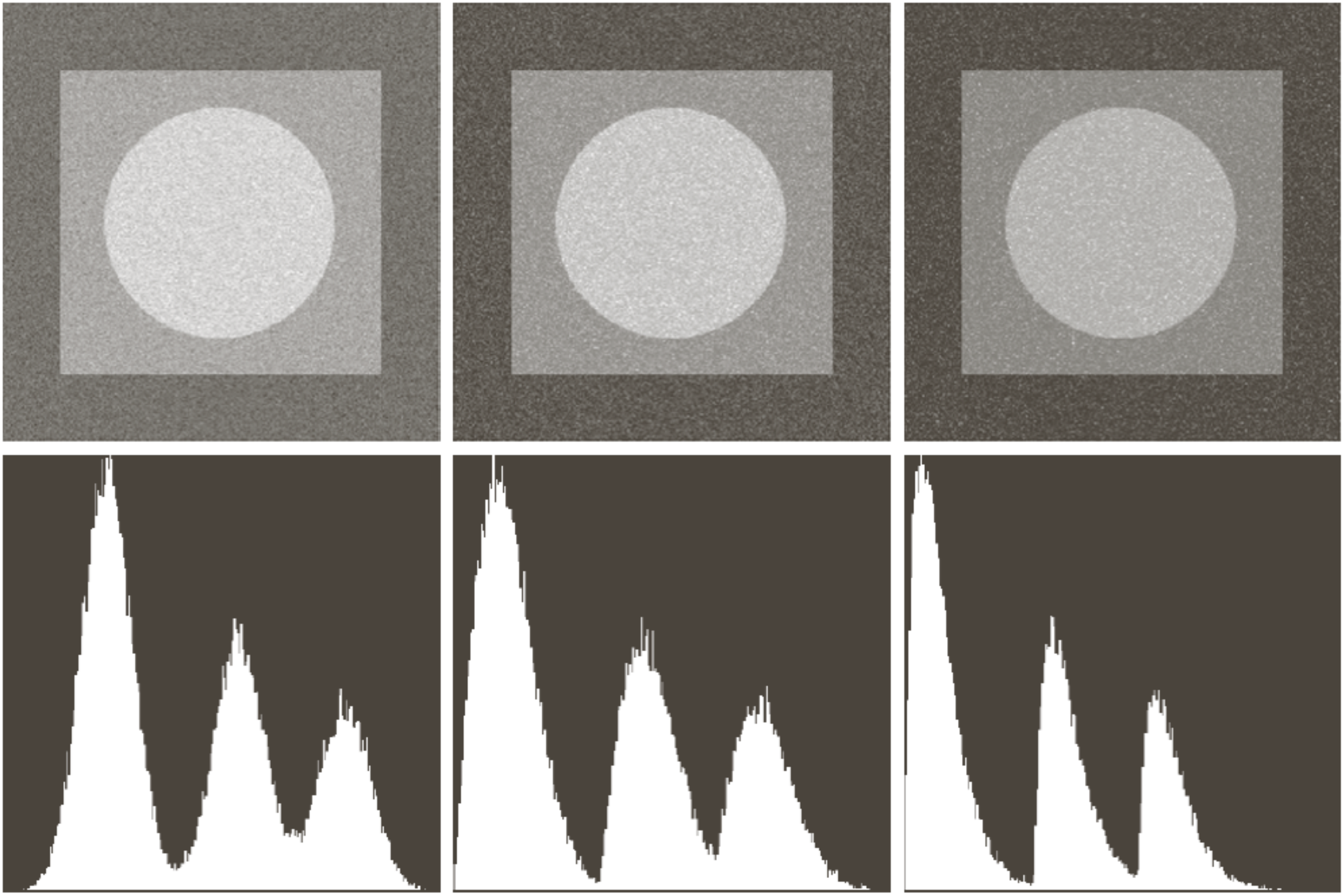
Noise Probability Density Functions

Exponential Noise

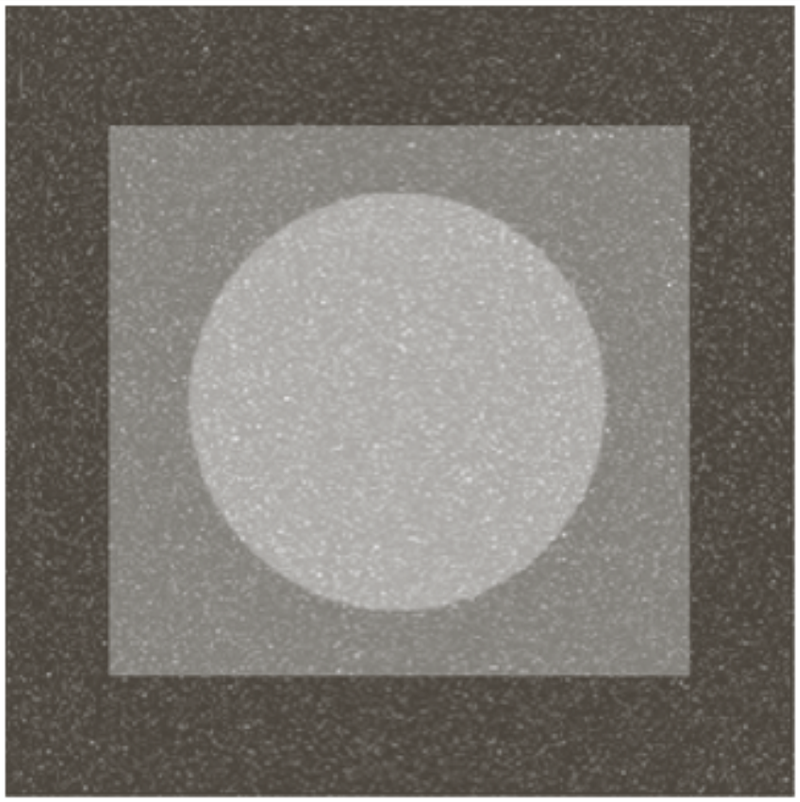
Uniform Noise

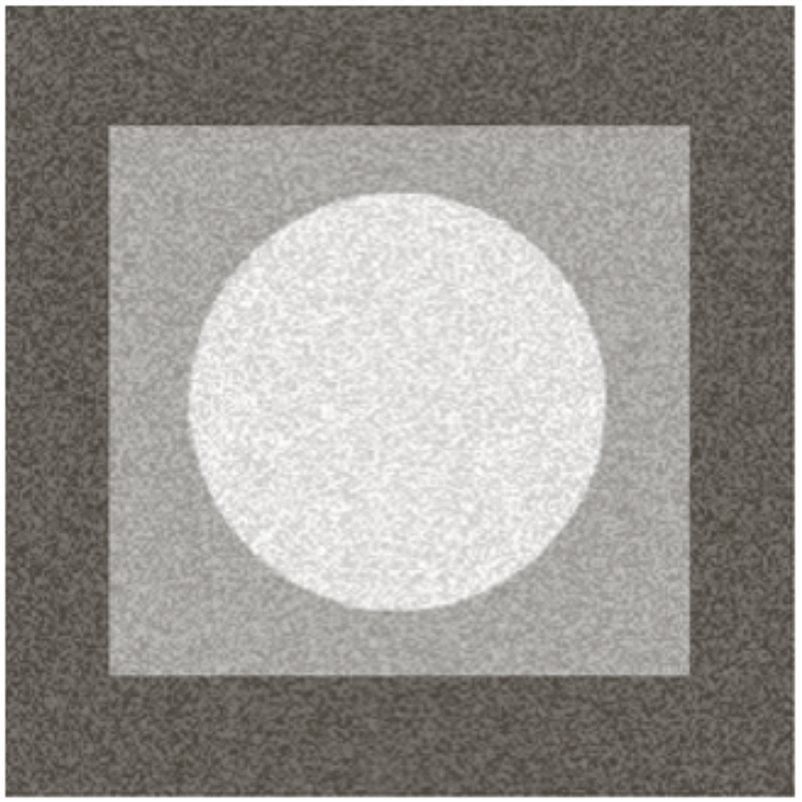
Impulse (salt-and-pepper) Noise

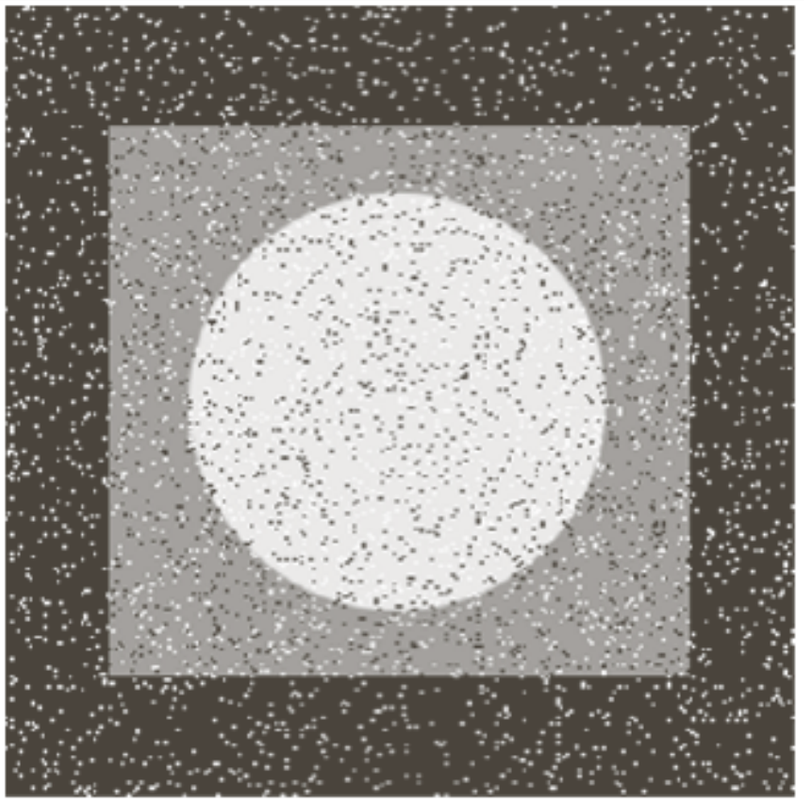


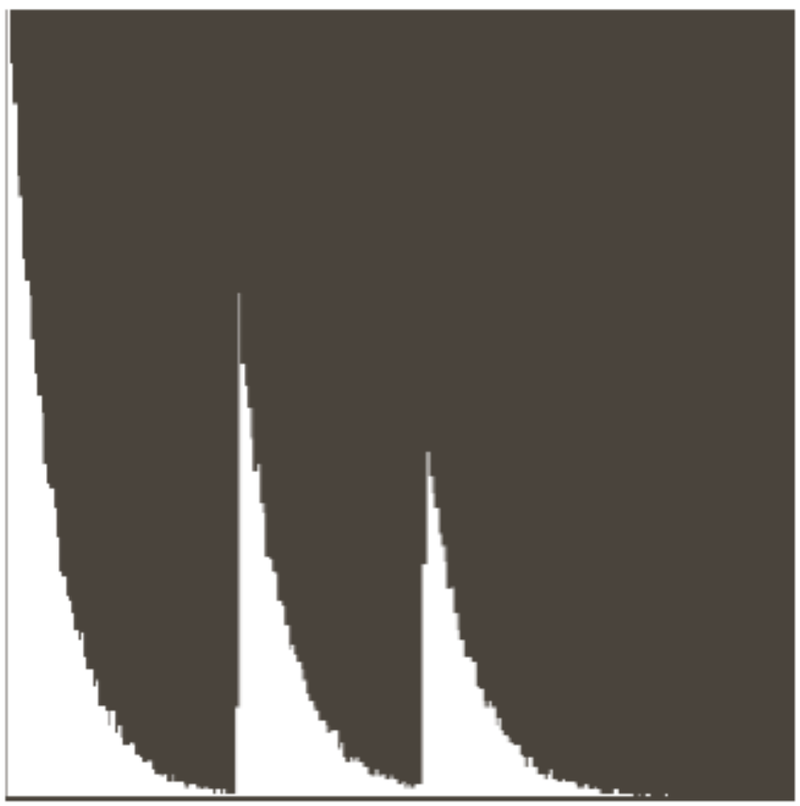


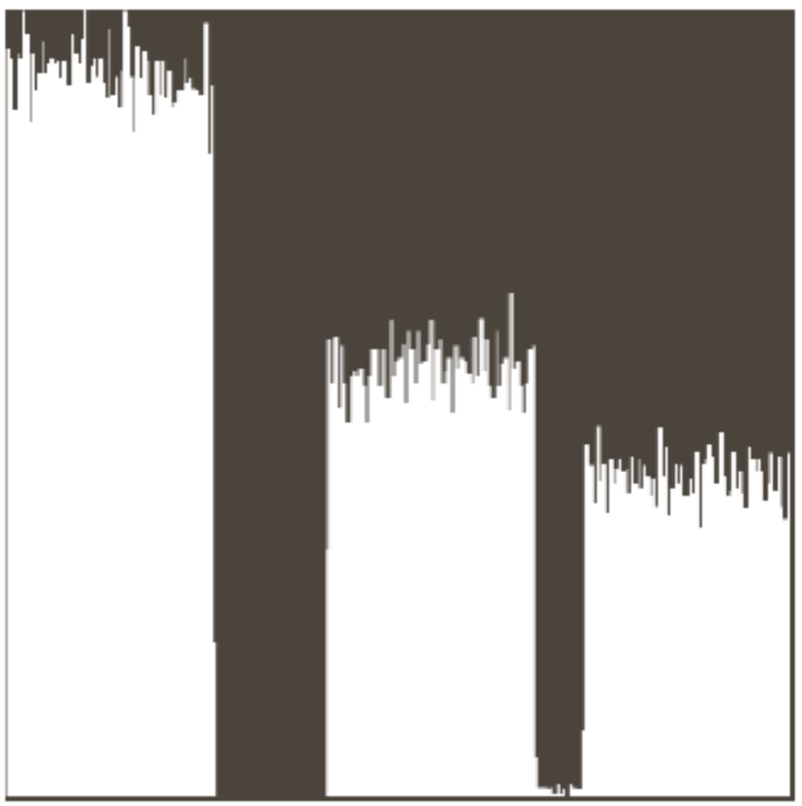
Gaussian Rayleigh Gamma











Exponential

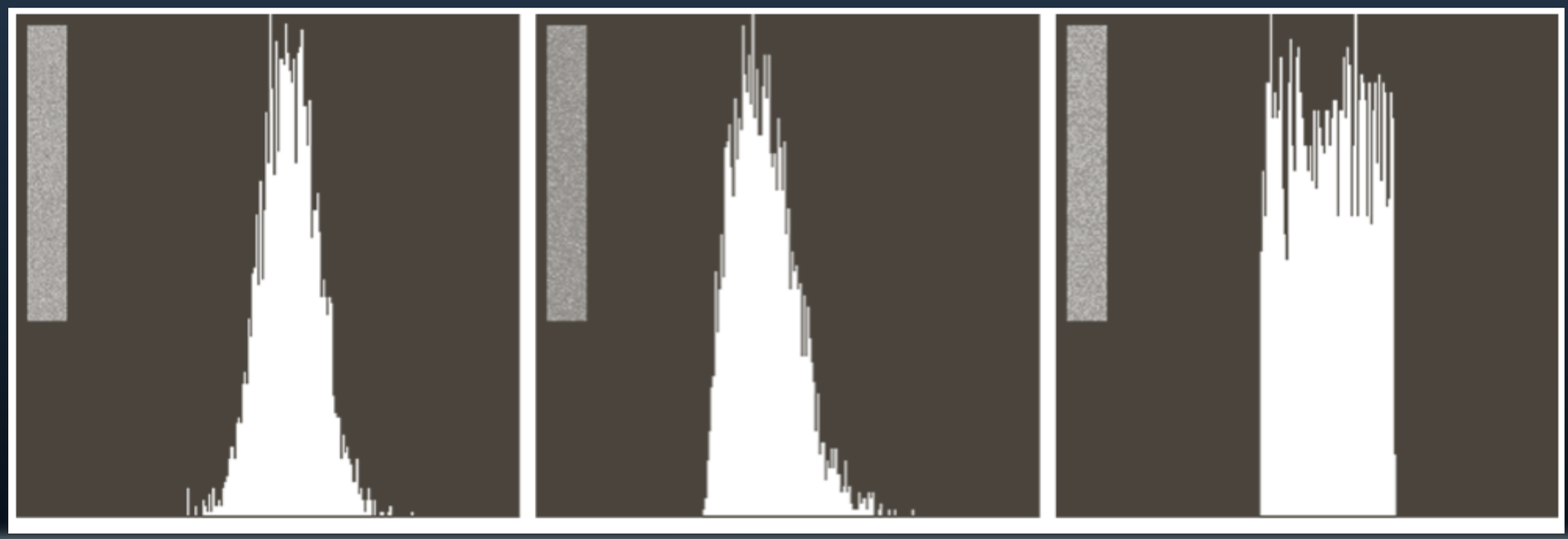
Uniform

Salt & Pepper

Estimate of the Noise Parameters

- 由感測器的特性或規格說明加以評估
- 運用平均值與標準差

$$\mu = \sum z_i p(z_i) \quad \circ \sigma^2 = \sum (z_i - \mu)^2 p(z_i)$$



Restoration – in Spatial domain

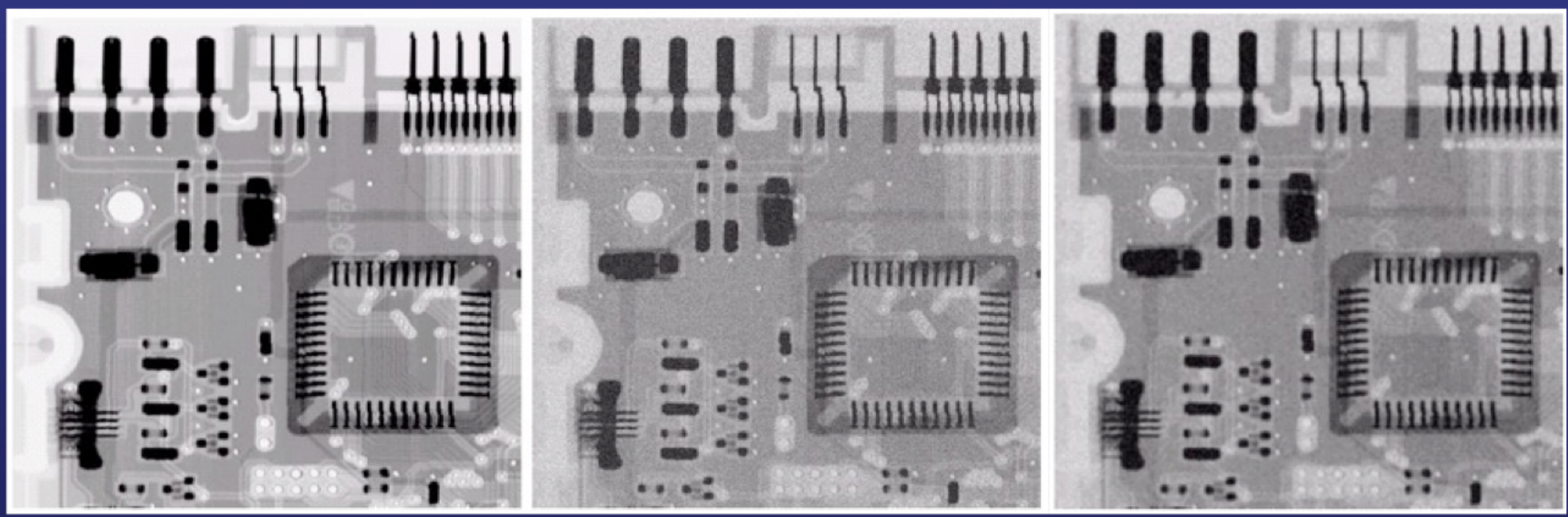
- Presence of Noise Only

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

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

Arithmetic Mean Filter

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



Average

- arithmetic mean 算數平均 $\frac{a+b}{2}$
- geometric mean 幾何平均 $\sqrt{ab}$
- harmonic mean 調和平均 $\frac{2}{\frac{1}{a}+\frac{1}{b}}$

Geometric mean filter

- Geometric mean filter

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

Harmonic mean filter

- fails for pepper noise.

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

Contraharmonic mean filter

- Q > 0 : pepper noise
- Q < 0 : salt noise

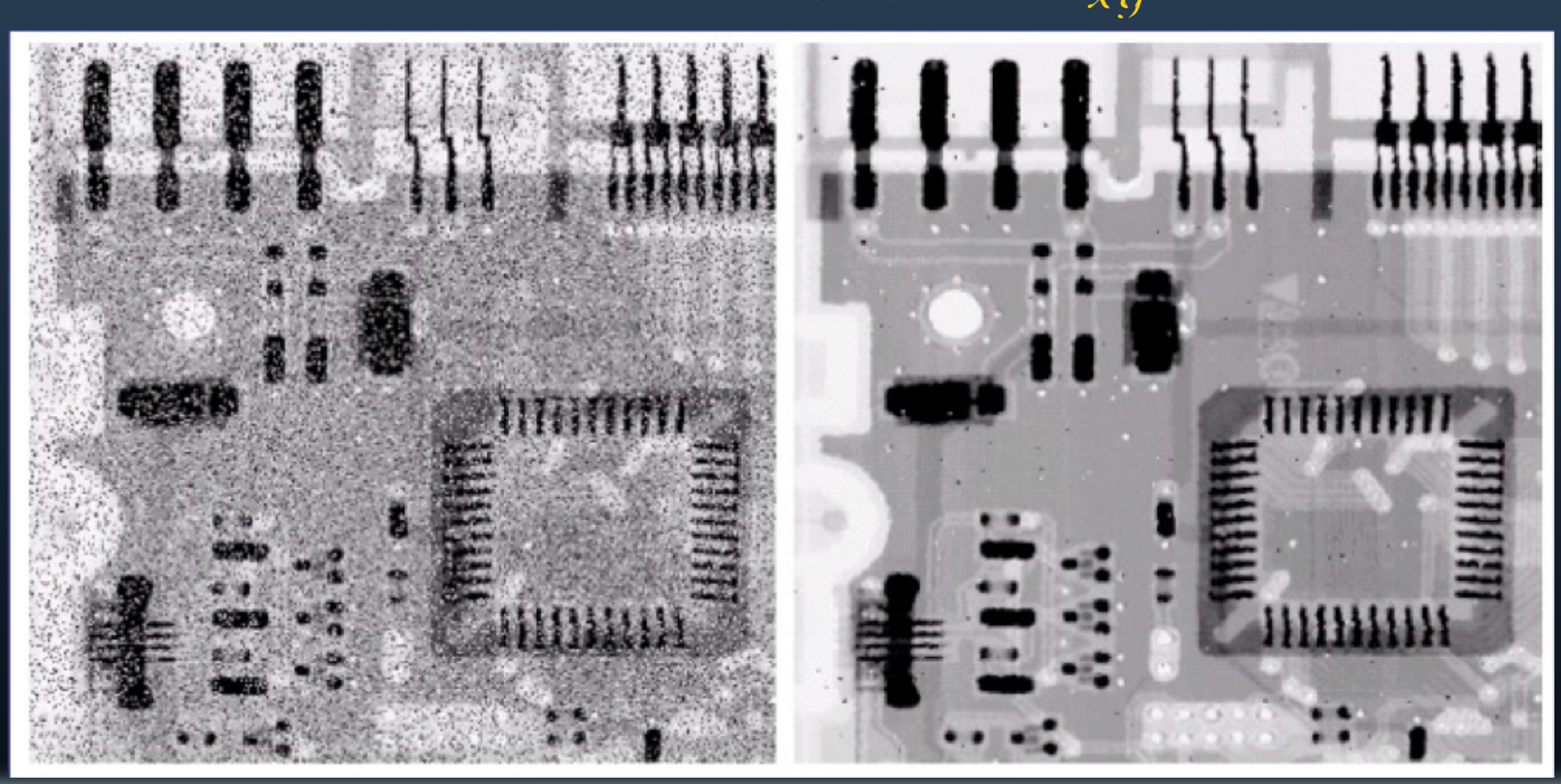
- Q = 0 : arithmetic mean filter
- Q = -1 : harmonic mean filter

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

Order-Statistics Filters Filter

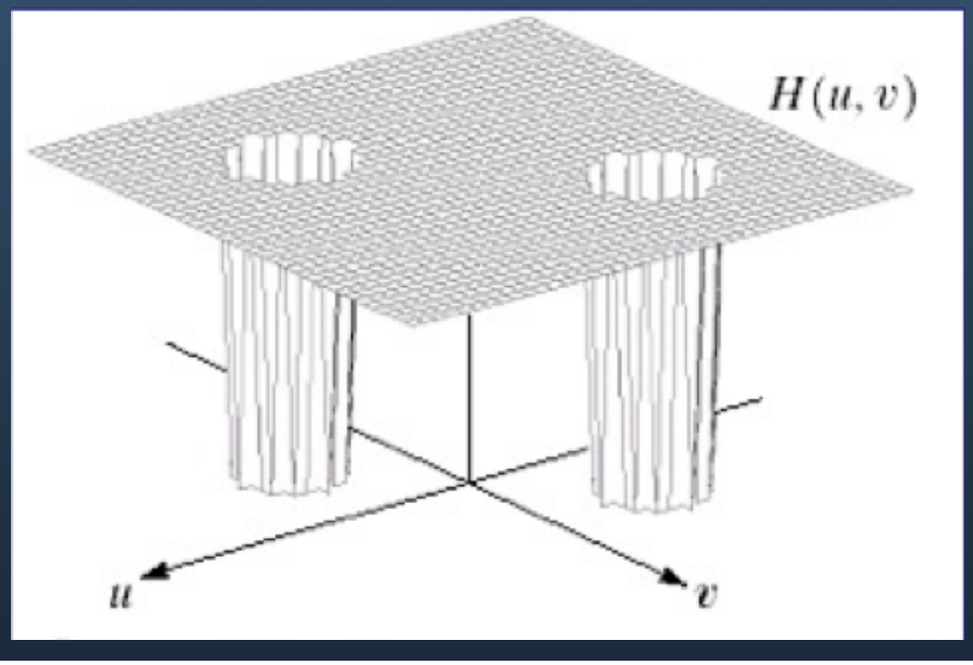
- Median Filter

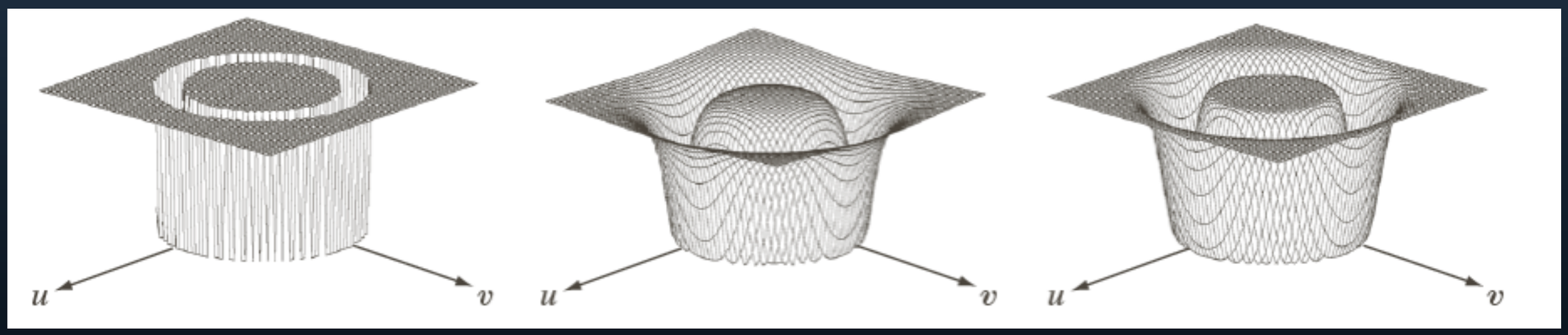
$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\}$$



Noise Reduction – in Frequency domain

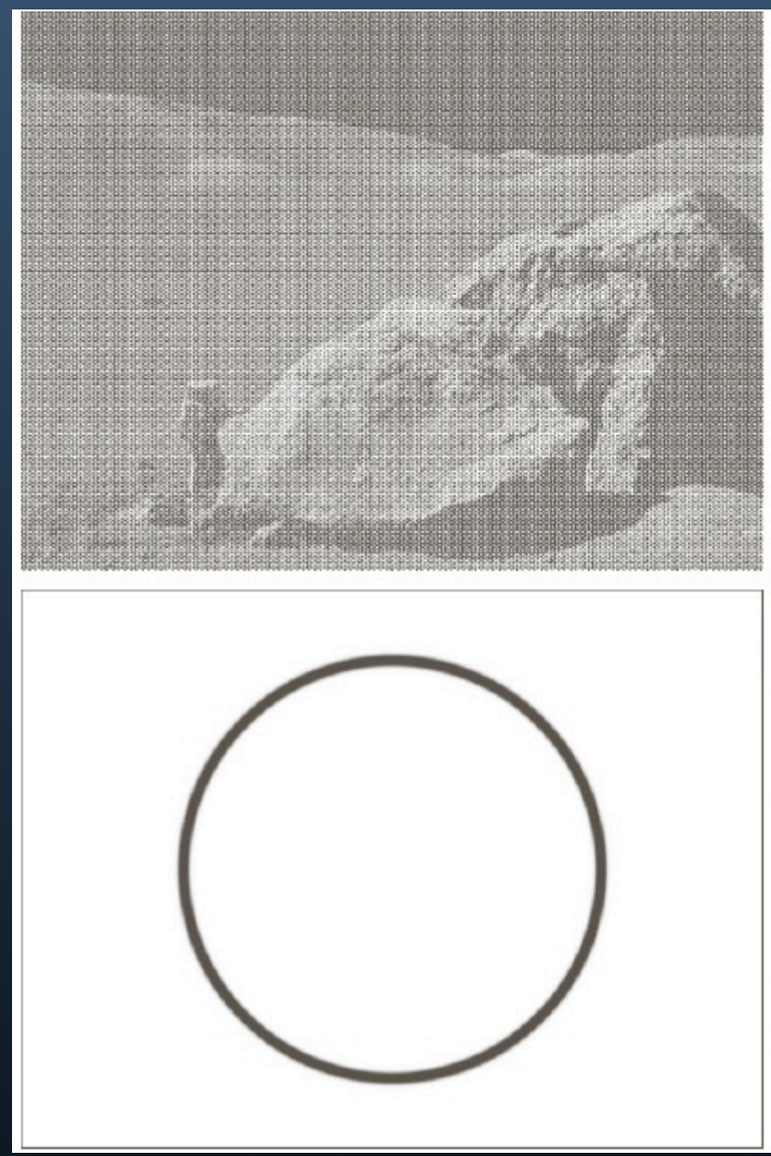
- Bandreject Filter
- Bandpass Filter
- Notch Filter

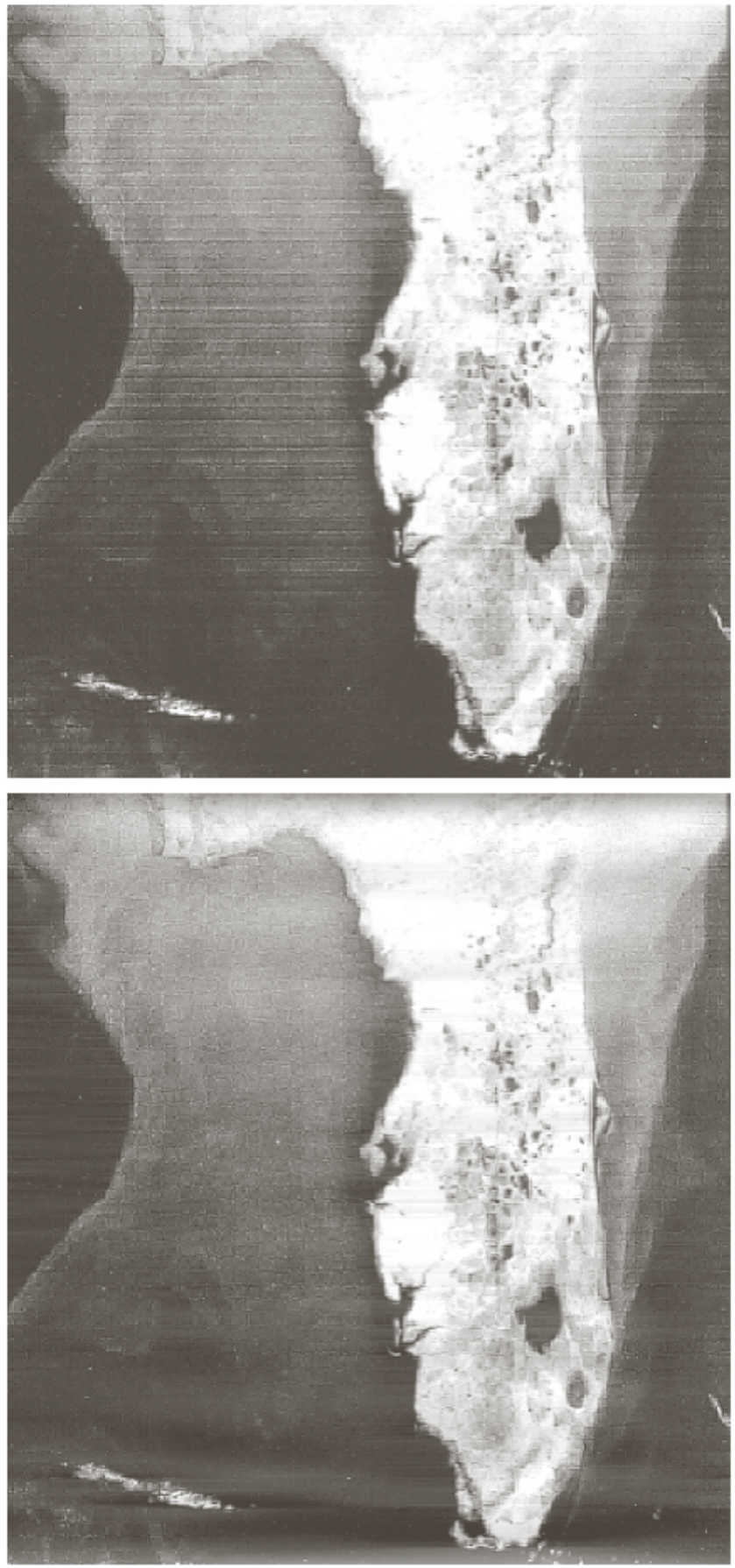


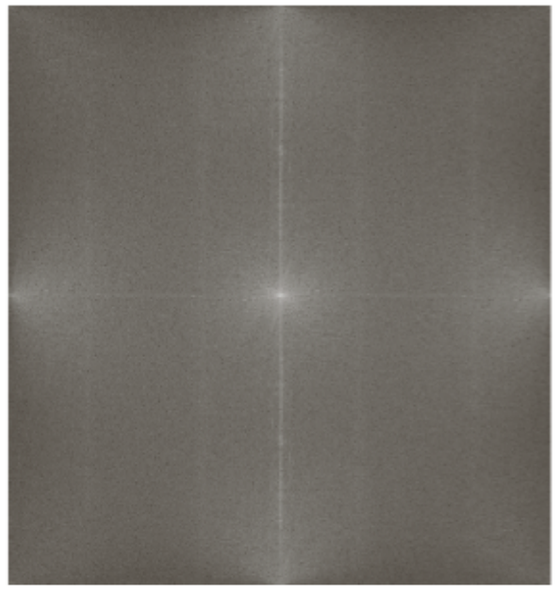


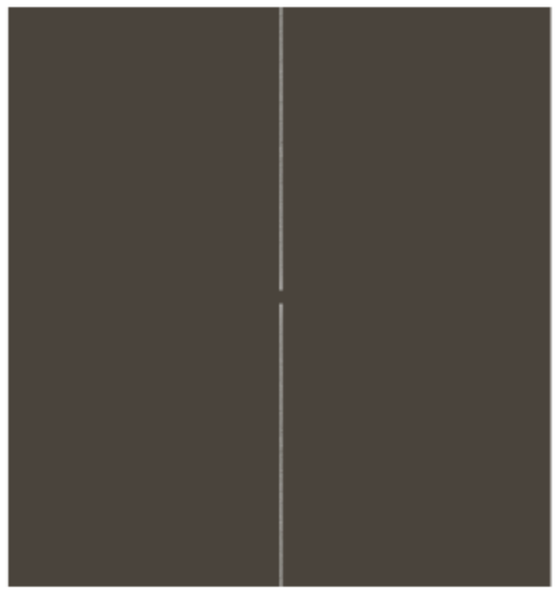
Periodic Noise

- Spatially dependent noise
- Reduced by frequency domain filtering

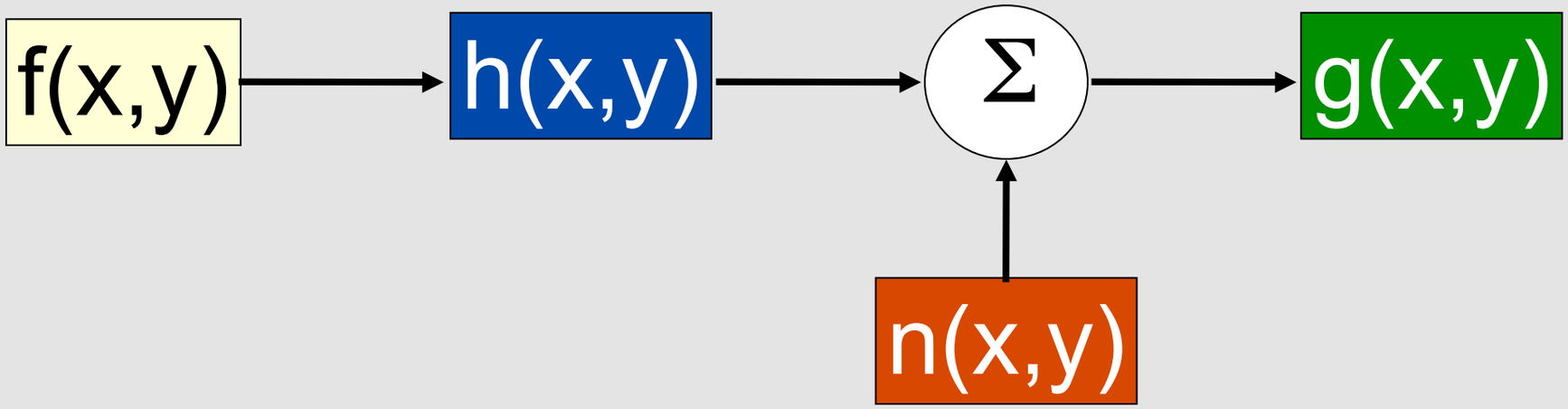








Estimating Degradation func.



Degradation Model: g = h*f + n

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

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

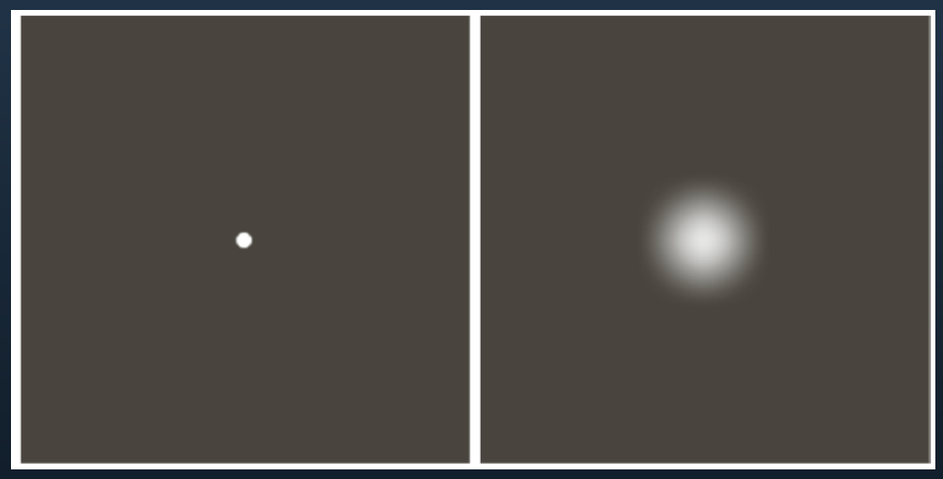
Estimating Degradation func.

- Observation
  - 取影像中具有強烈訊號的子影像 $g_s(x,y)$
  - 建立與 $g_s(x,y)$ 相同大小的ideal image $\hat{f}_s(x,y)$
  - 假設noise可忽略:

$$H_s(u,v) = \frac{G_s(u,v)}{\hat{F}_s(u,v)}$$

Estimating Degradation func.

- Experimentation
  - 調整攝影機設定參數來取得與degraded image相似之影像
  - 以該設定對點光源取樣
  - $H(u,v) = \frac{G(u,v)}{A}$



→ Impulse Response

Estimating Degradation func.

- Modeling
  e.g.
  大氣紊流

Approach

f(x,y)

↓

Build degradation model

↓

Analyze using algebraic techniques

↓

Formulate restoration algorithms

↓

Implement using Fourier transforms

↓

$\hat{f}(x,y)$

⋯⋯▸ $g = h*f + n$

⋯⋯▸ $\underline{g} = H\underline{f} + \underline{n}$

⋯⋯▸ $\underline{\hat{f}} = H^{-1}\underline{g}$

⋯⋯▸ $\hat{F}(u,v) = G(u,v)/H(u,v)$

Inverse Filtering

$$\hat{F}(u,v) = \frac{G(u,v)}{H(u,v)}$$

$$\hat{F}(u,v) = F(u,v) + \frac{N(u,v)}{H(u,v)}$$

- When noise is a random function, …
- When H has zero or very small values, …

Other Filters

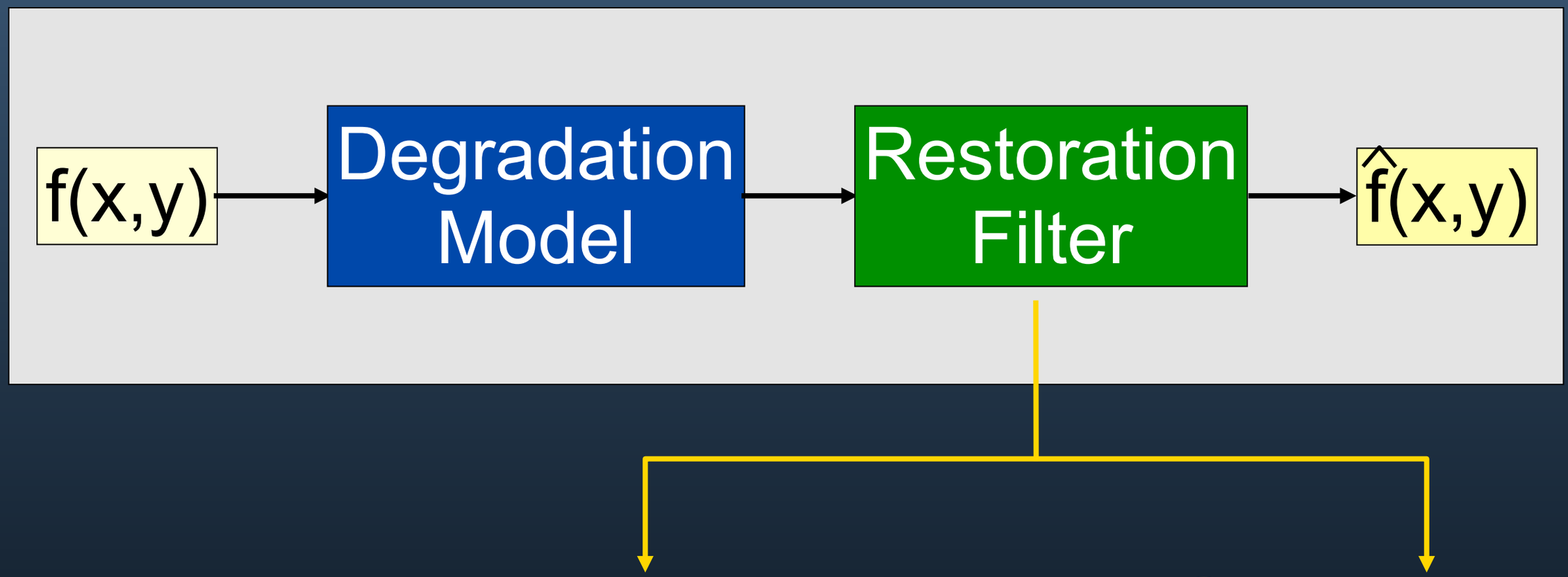
- Wiener Filter
  - 最小平均平方誤差濾波
- Constrained least squares filter
- Geometric Mean Filter

Example 5.12: Wiener Filtering

a b c

FIGURE 5.28 Comparison of inverse and Wiener filtering. (a) Result of full inverse filtering of Fig. 5.25(b). (b) Radially limited inverse filter result. (c) Wiener filter result.

Restoration Model



Unconstrained

- Inverse Filter
- Pseudo-inverse Filter

Constrained

- Wiener Filter