Digital Image Processing and Pattern Recognition

E1528

Fall 2022-2023

Lecture 9

Image Restoration

INSTRUCTOR

DR / AYMAN SOLIMAN

➢ Contents

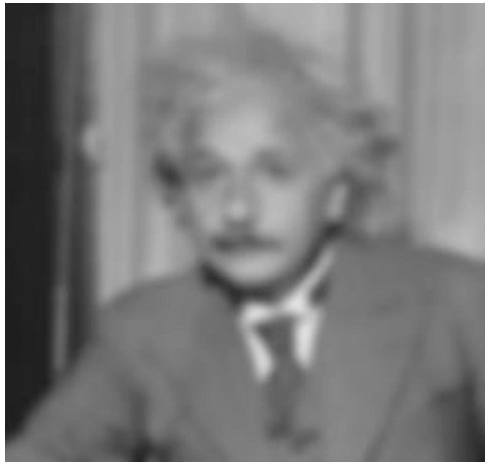
- ➢ Image Restoration
- ➢ Noise Types
- ➢ Recovering From Noise
- ➢ Estimating the degradation function
- ➢ Image Reconstruction from Projections

Image Restoration

- Image restoration aims to improve an image that has suffered from linear degradation.
- Degradation considered noise in the acquisition, transmission problems, etc.
- The purpose of image restoration is to reconstruct the original image from a degraded observation.

Distortion may arise from

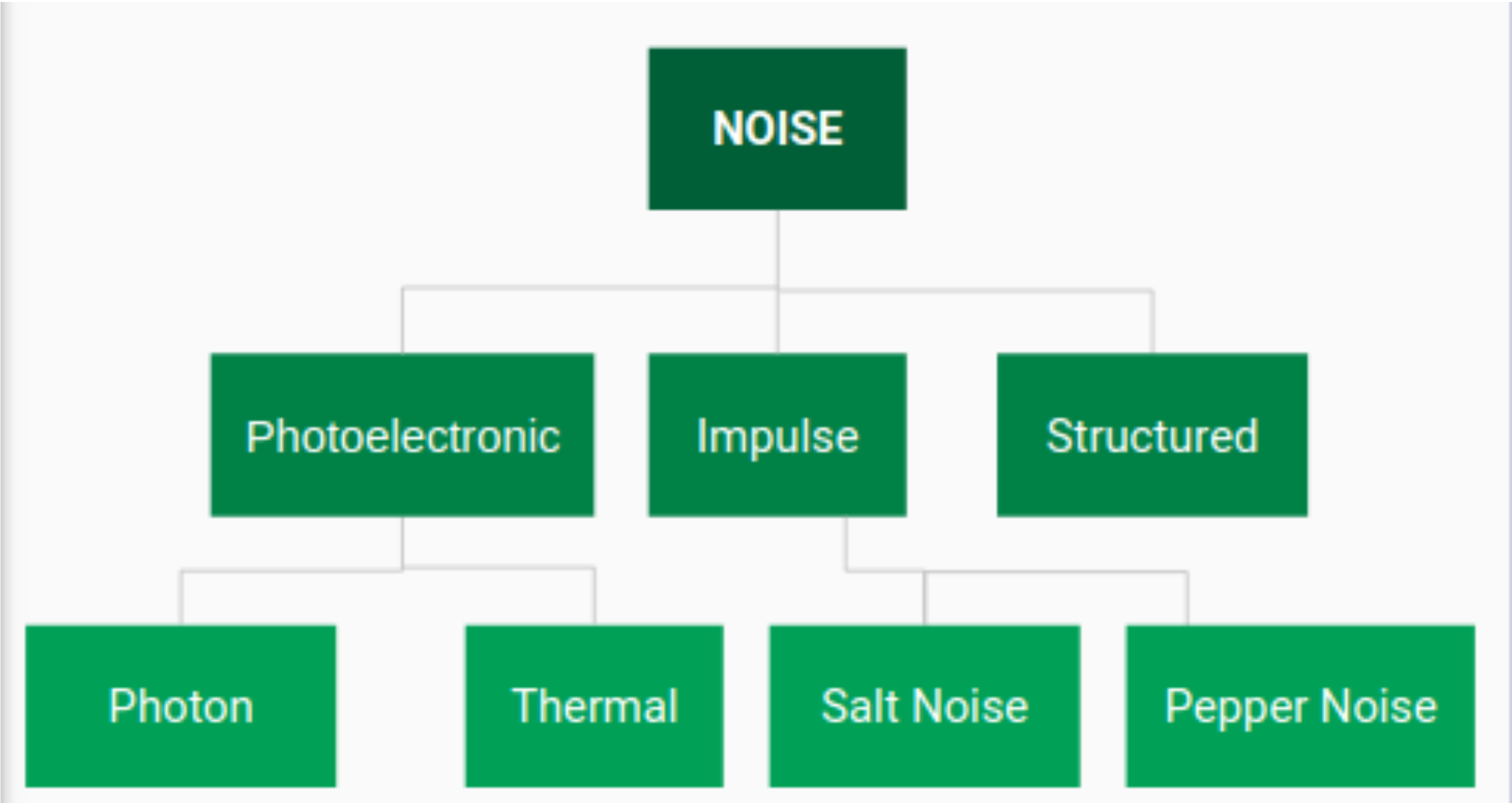
Out of focus blur

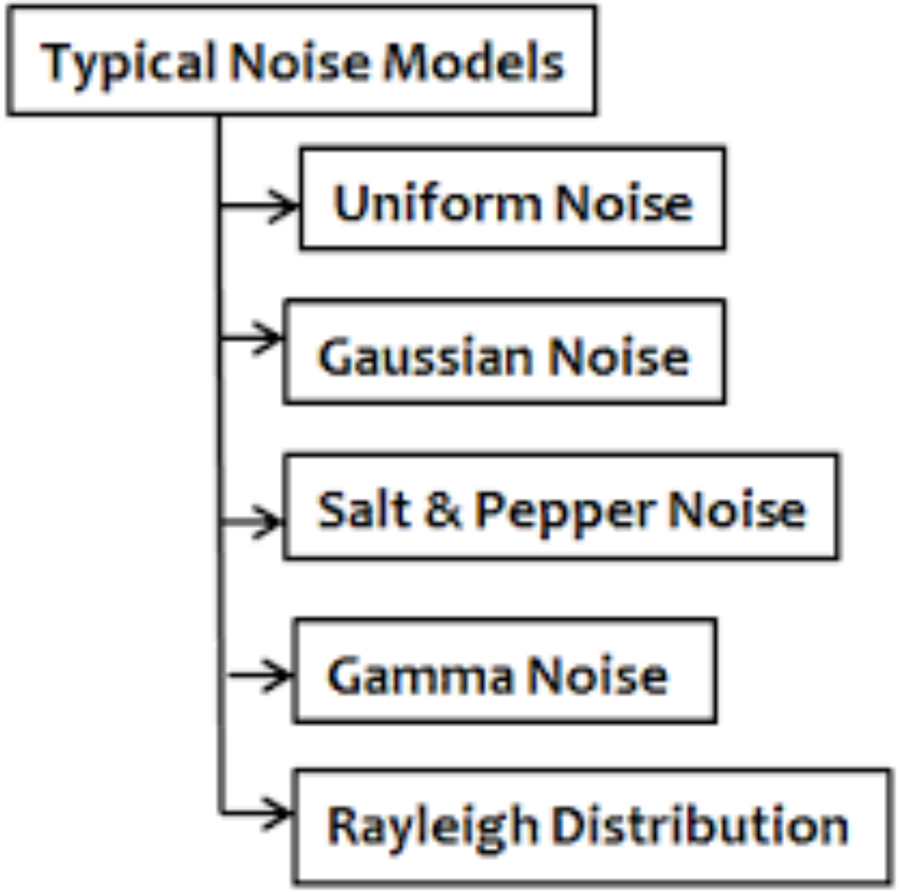


Motion Blur

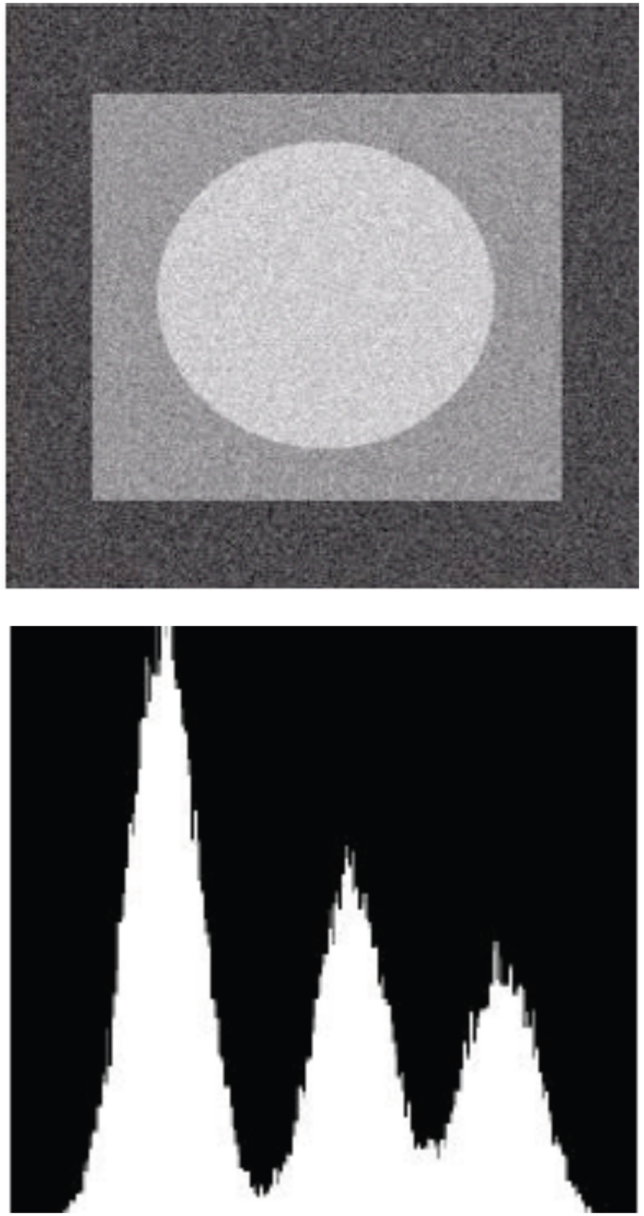
Additive Noise

Noise Types

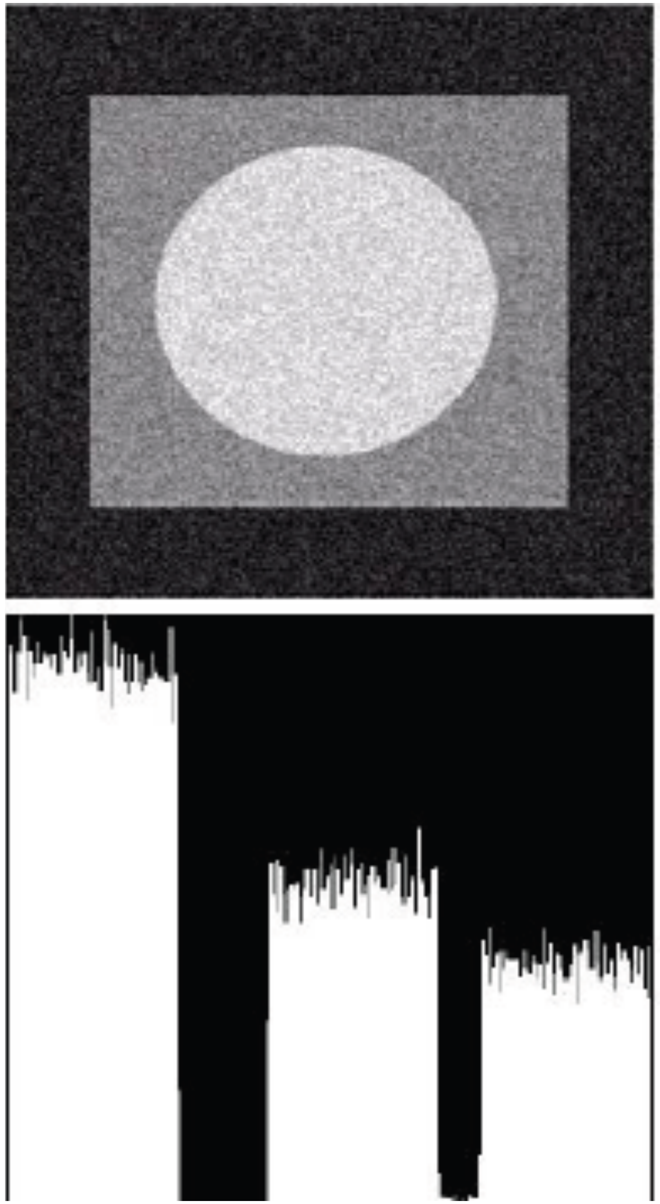

NOISE
Photoelectronic
Impulse
Structured
Photon
Thermal
Salt Noise
Pepper Noise


Typical Noise Models
Uniform Noise
Gaussian Noise
Salt & Pepper Noise
Gamma Noise
Rayleigh Distribution

Gaussian Noise



Uniform Noise



Recovering From Noise

Spatial Filters

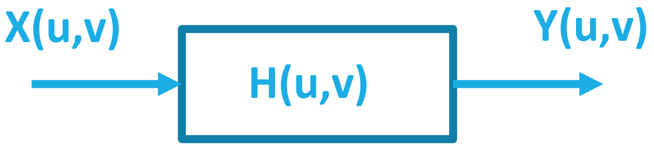
- Gaussian Filter
- Median Filter
- Mean Filter

Frequency Domain Filters

- Notch Filter
- LPF
- HPF

Blur Model

Frequency Domain

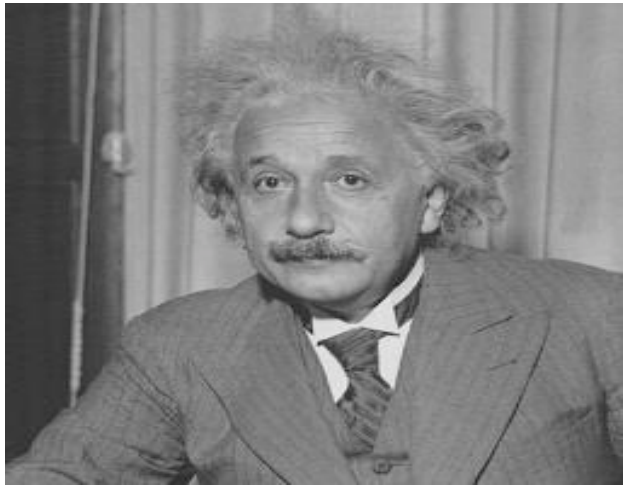


Blurring filter

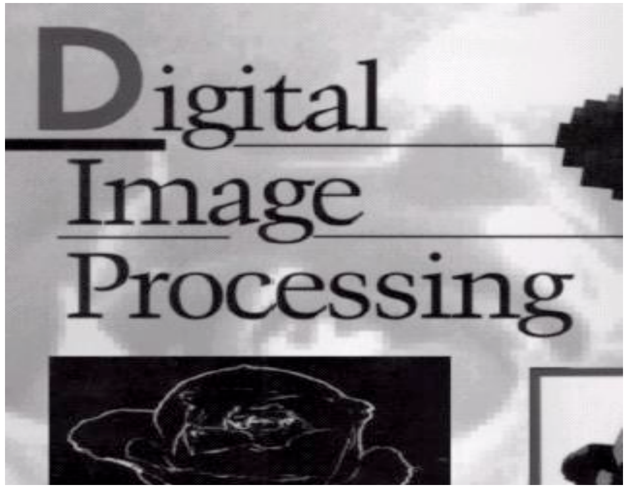
Spatial Domain

Blurring filter

Blurring Effect

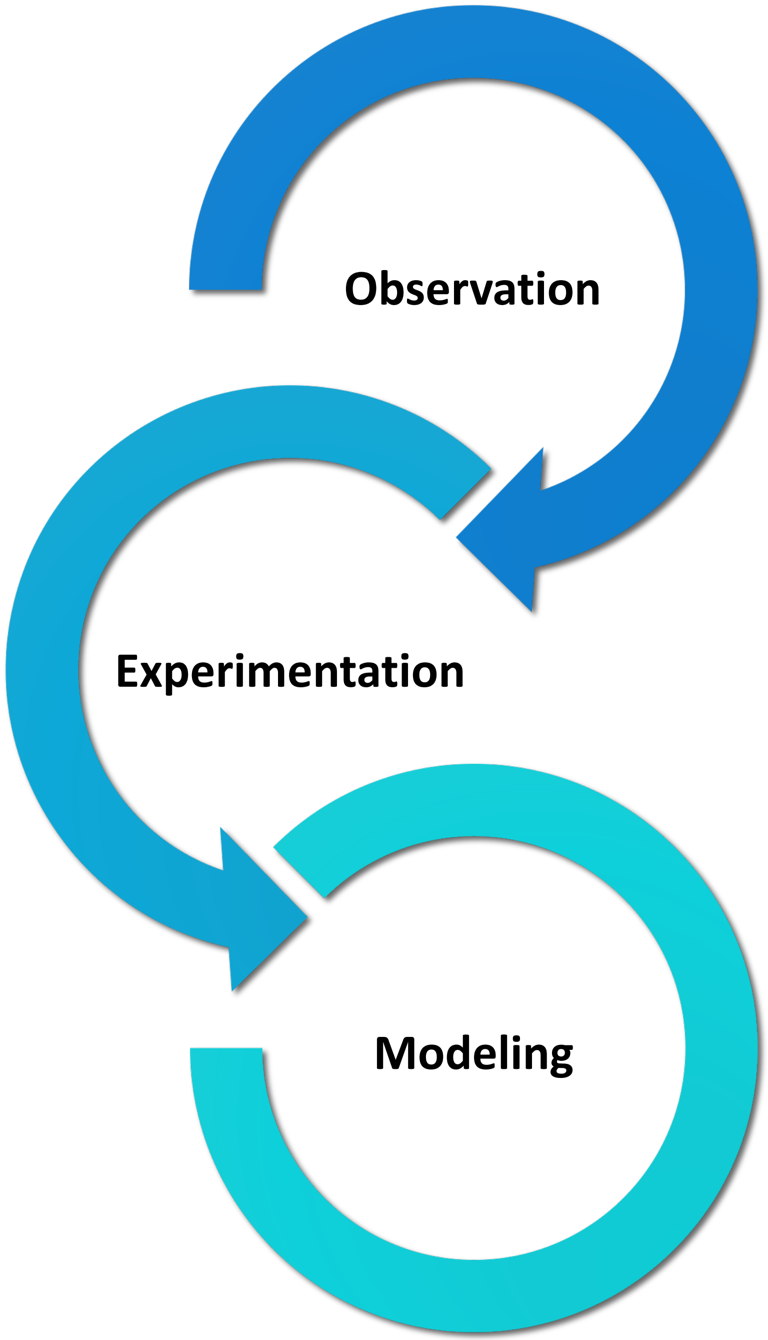


Gaussian Blur



Motion Blur

Estimating the degradation function



Estimating by observation

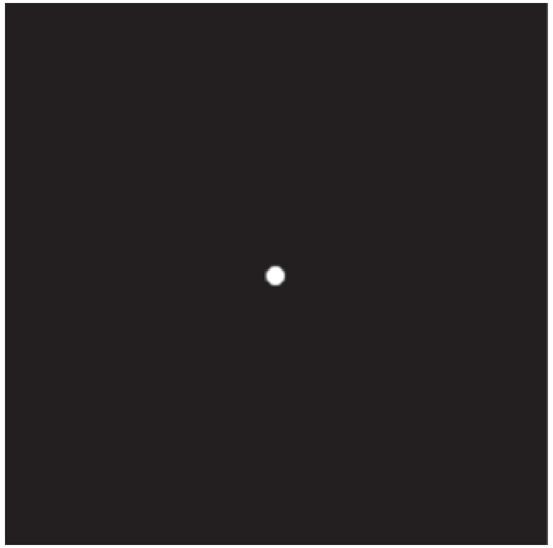
- Finding the information from the observed image.
- Identify a portion of the image that is visually unblurred [k(x,y)] and observed image [g(x,y)].
- The degradation function can be estimated by applying an inverse Fourier transform to the ratio of the Fourier transform of the observed image and the sub image.

$$H(U,V) = \frac{G(U,V)}{K(U,V)}$$

Estimating by Experimentation

- Obtain the impulse response by imaging small dot of light.

- Knowing that the Fourier transform of the impulse is a constant (A).



- The degradation function can be estimated by applying an inverse Fourier transform to the ratio of the Fourier transform of the observed image and the impulse function.

$$H(U,V) = \frac{G(U,V)}{A}$$

Estimating by Modeling

- A set of equations that approximate the real system.
- Scenario 1: Complete knowledge about the blur available.
- Scenario 2: There is only a partial knowledge of the blurring function available.
- Scenario 3: There is no knowledge about the blurring function **(Blind Restoration).**

$$H(u,v) = e^{-k(u^2+v^2)^{5/6}}$$

Image Restoration methods can be divided into two classes

Blind

- In which the blurring operator is unknown

Non-blind

- In which the blurring operator is known

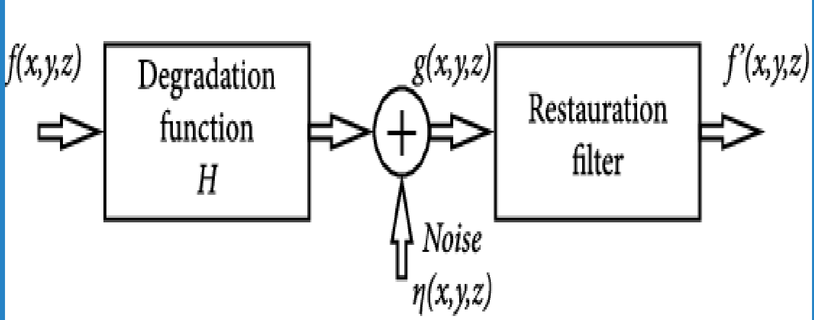
Non-Blind Deblurring

- Inverse Filter
- Pseudo inverse Filter
- Wiener Filter

Blind Deblurring

- Iterative Blind Deblurring
- Non-Iterative Blind Deblurring

Degradation Model



- The image can be degraded using Filter and Noise.
- The degraded image can be described by the following equation:

$$g = H \times f + \eta$$

Where:

g………… Degraded or blurred image

H………... Degradation Function

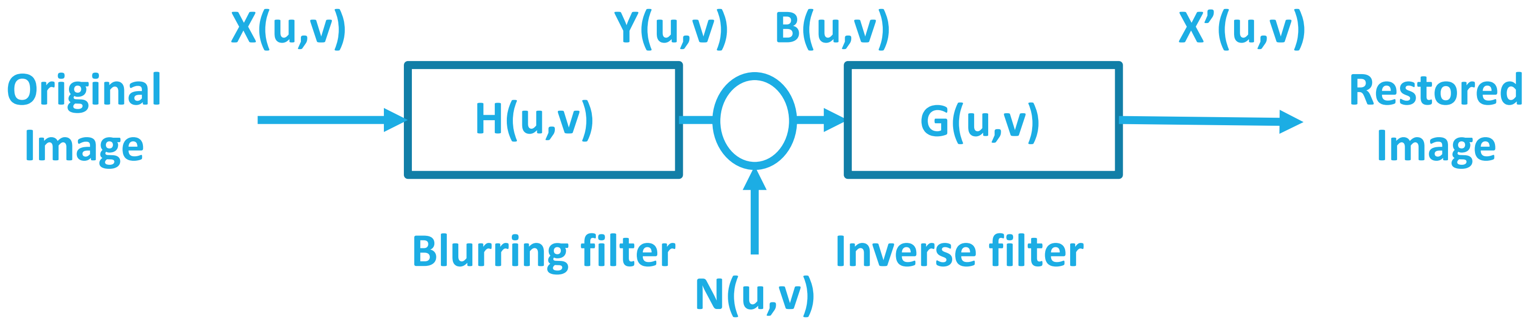
f………… The Original image

η ………… Additive Noise

Non-Blind Deblurring

i. Inverse Filter

$$G(u,v) = \frac{1}{H(u,v)}$$

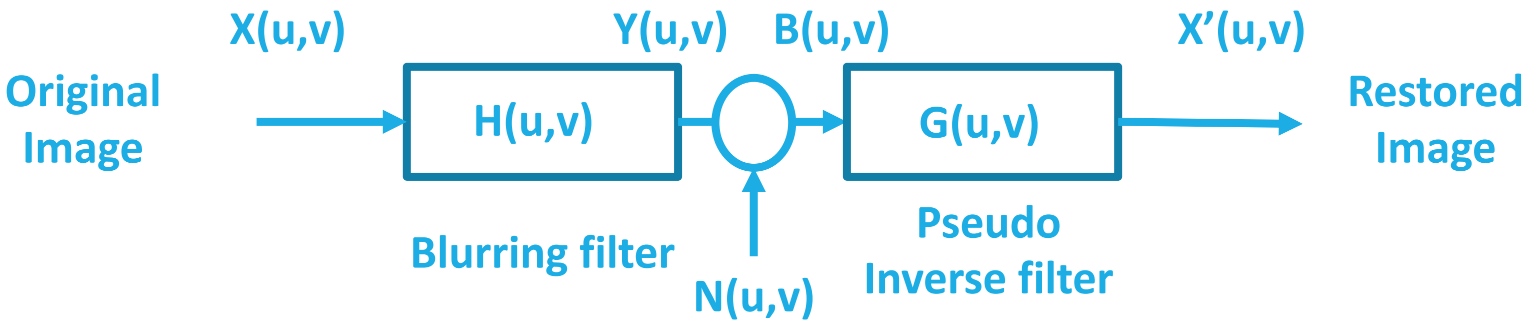


$$\because B(u,v) = X(u,v)H(u,v) + N(u,v)$$

$$\therefore X'(u,v) = X(u,v) + \frac{N(u,v)}{H(u,v)}$$

ii. Pseudo Inverse Filter

$$G(u,v) = \begin{cases} \dfrac{1}{H(u,v)} & |H(u,v)| \geq \delta \\ 0 & |H(u,v)| < \delta \end{cases}$$



$$\therefore X'(u,v) = X(u,v) + \frac{N(u,v)}{H(u,v)}$$

iii. Wiener Filter

$$G(u,v) = \frac{H^*(u,v)}{|H(u,v)|^2 + K}$$

$$K = \frac{\delta_W^2}{\delta_X^2}$$

δ_W^2 → **Noise Power**

δ_X^2 → **Signal Power**

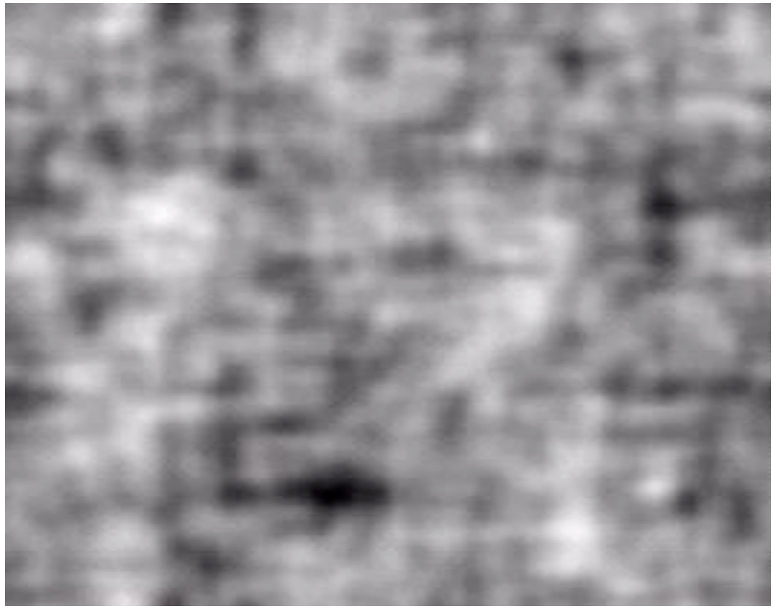
For H(u,v) = 1:

Wiener denoising Filter

$$G(u,v) = \frac{1}{1+K} = \frac{\delta_X^2}{\delta_X^2 + \delta_W^2}$$

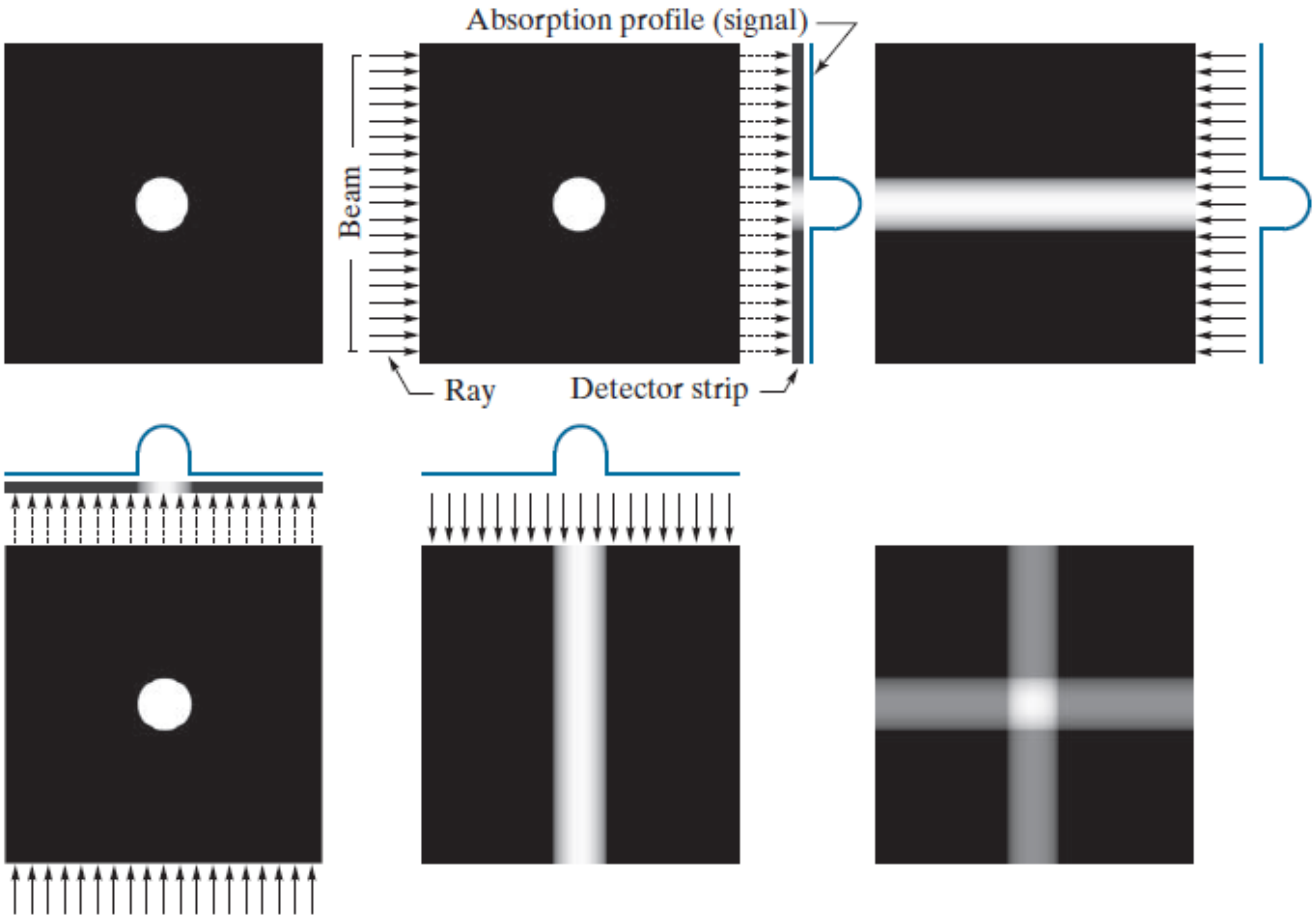
Blurred Image

Inverse Filtering



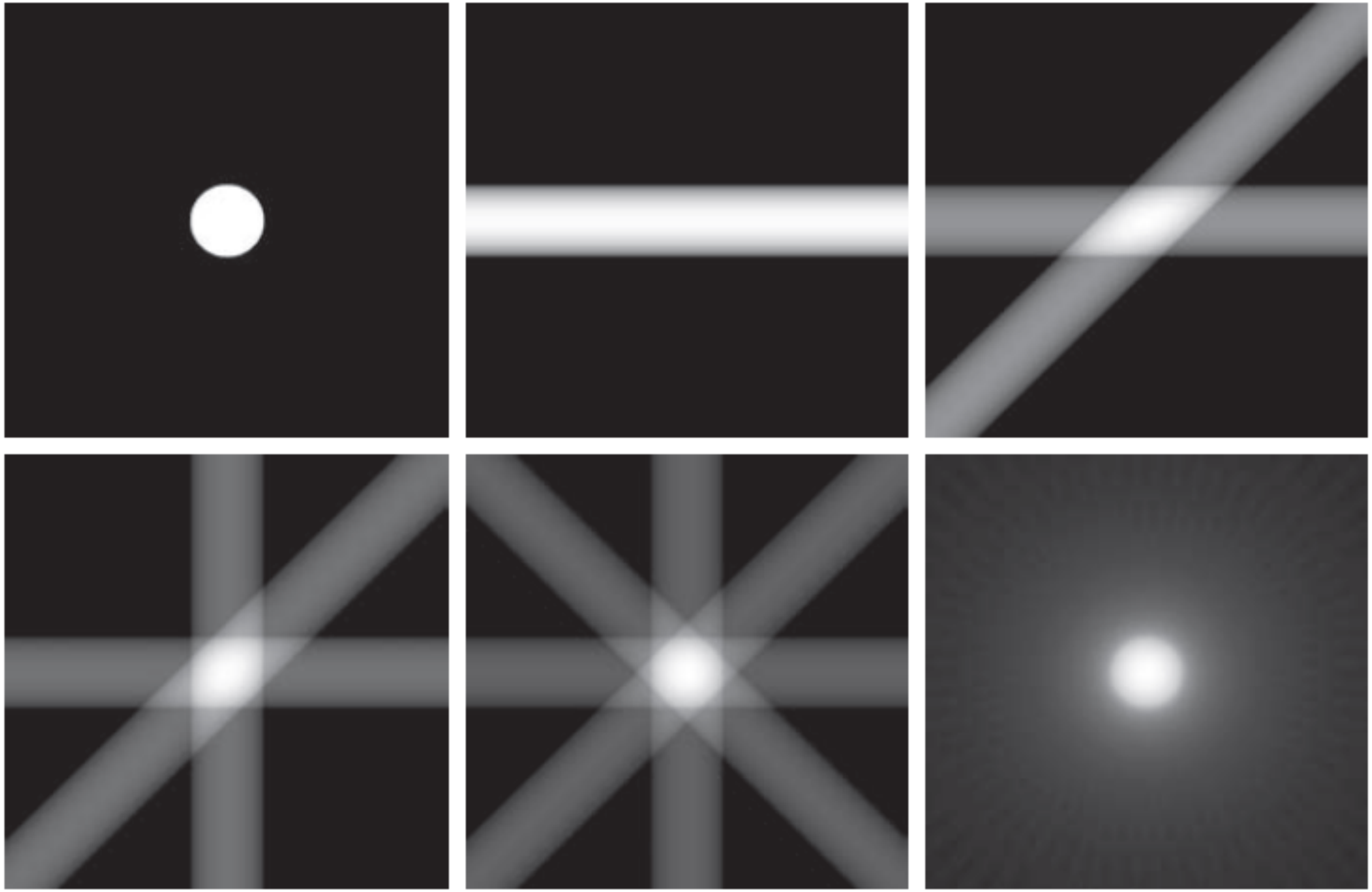
Wiener Filtering

Image Reconstruction from Projections



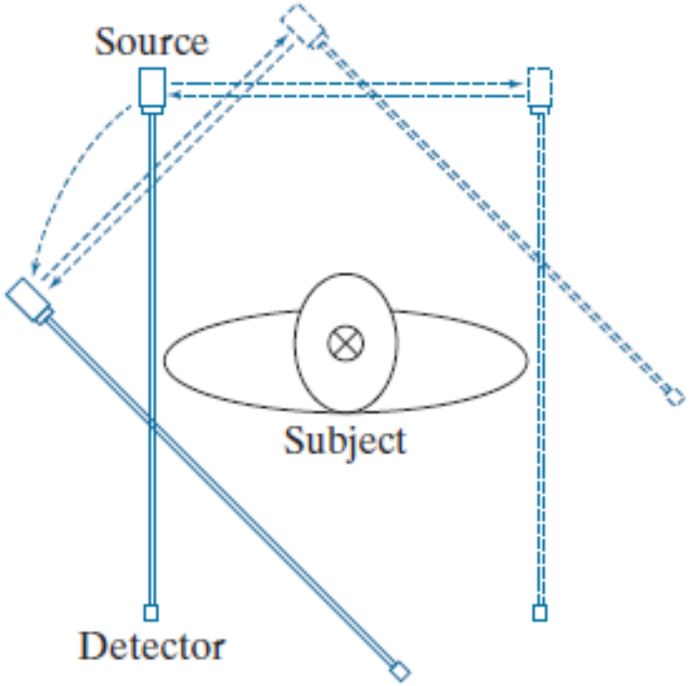
As the number of projections increases, the amplitude strength of non-intersecting back projections decreases

Reconstruction with 32 back projections 5.625° apart.



CT Generations

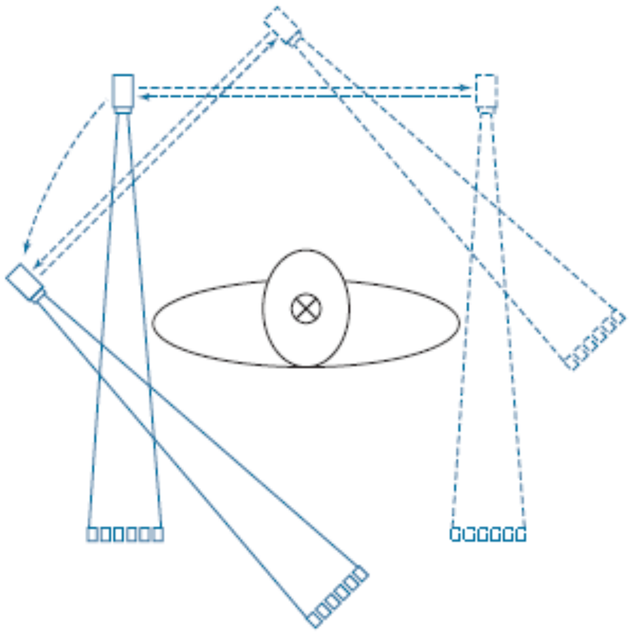
First Generation



Pencil Beam and single detector

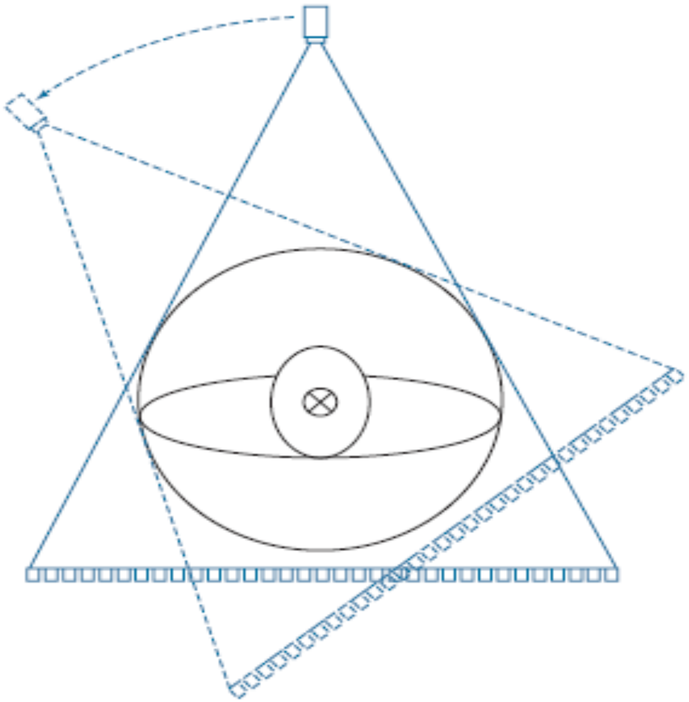
- **A projection is generated by measuring the output of the detector at each increment of translation.**

Second Generation



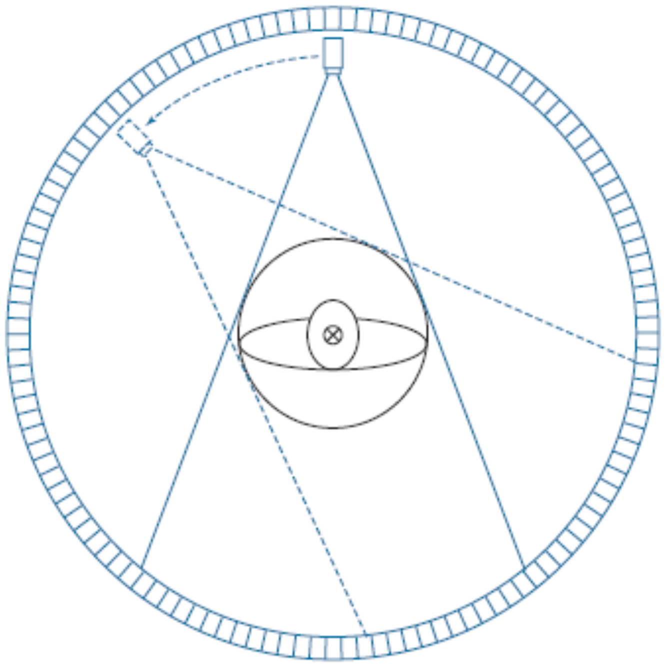
- Operate on the same principle as G1 scanners, but the beam used is in the shape of a fan. This allows the use of multiple detectors.

Third Generation



- G3 scanners employ a bank of detectors to cover the entire field of view of a wider beam.
- Each increment of angle produces an entire projection, eliminating the need to translate the source/detector pair, as in G1 and G2 scanners

Fourth Generation



- **Employing a circular ring of detectors (on the order of 5000 individual detectors), only the source must rotate.**
- **The key advantage of G3 and G4 scanners is speed;**
- **The key disadvantages are cost and greater X-ray scatter.**


Thank you