A Lecture on

Introduction to

Image Restoration

Presented By
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Lecture on Image Restoration

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Objective of Two Hour Presentation

"To introduce the basic concept of Image Restoration in Digital Image Processing"

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Kalyan Acharjya

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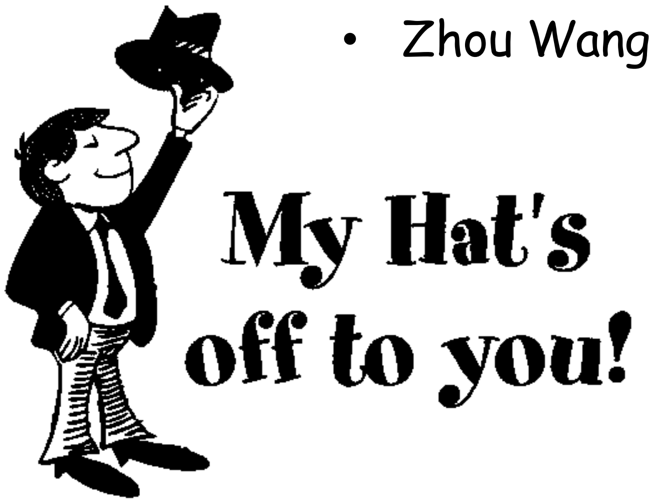
- Yu Hen Yu.
- Zhou Wang, University of Texas.



Outlines

- What is Image Restoration.
- Image Enhancement vs. Image Restoration.
- Image Degradation Model.
- Noise Models.
- Estimation of Degradation Model.
- Restoration Techniques.
- Some Basics Filter
- Advanced Image Restoration.
- Conclusions.
- Tools for DIP.
- Applications.

Lets start

- **What is Image Restoration.**
- Image Enhancement vs. Image Restoration.
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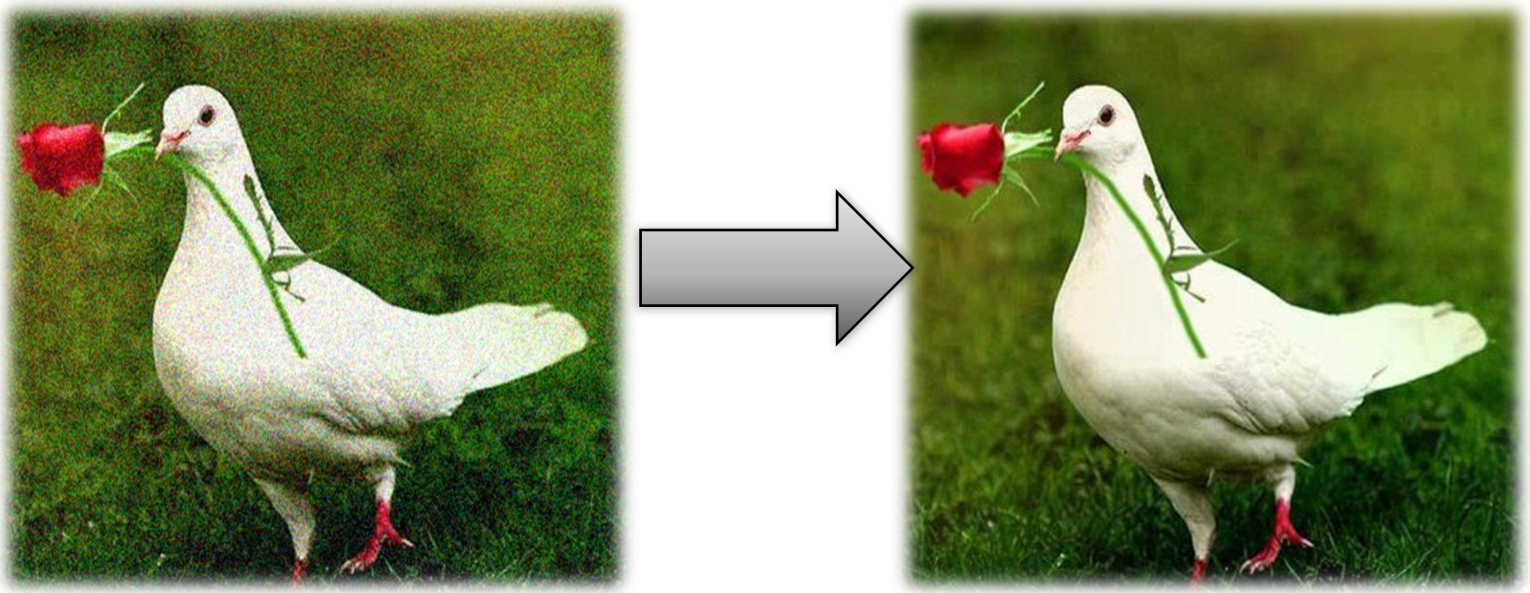
What is Image Restoration.



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.

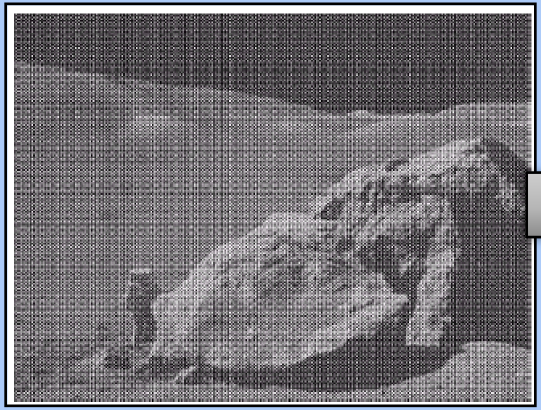


Fig: Degraded image

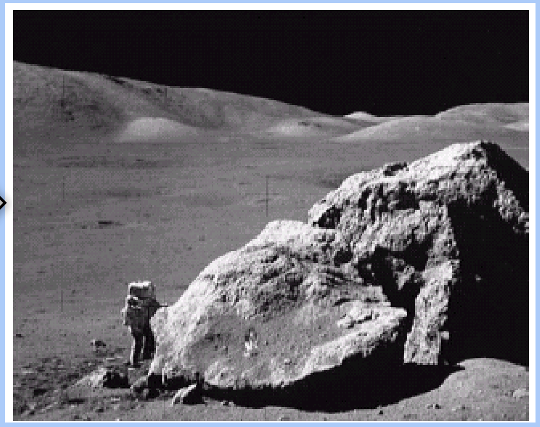


Fig: Restored image

Where we reached?

- What is Image Restoration.
- **Image Enhancement vs. Image Restoration.**
- Image Degradation Model.
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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.

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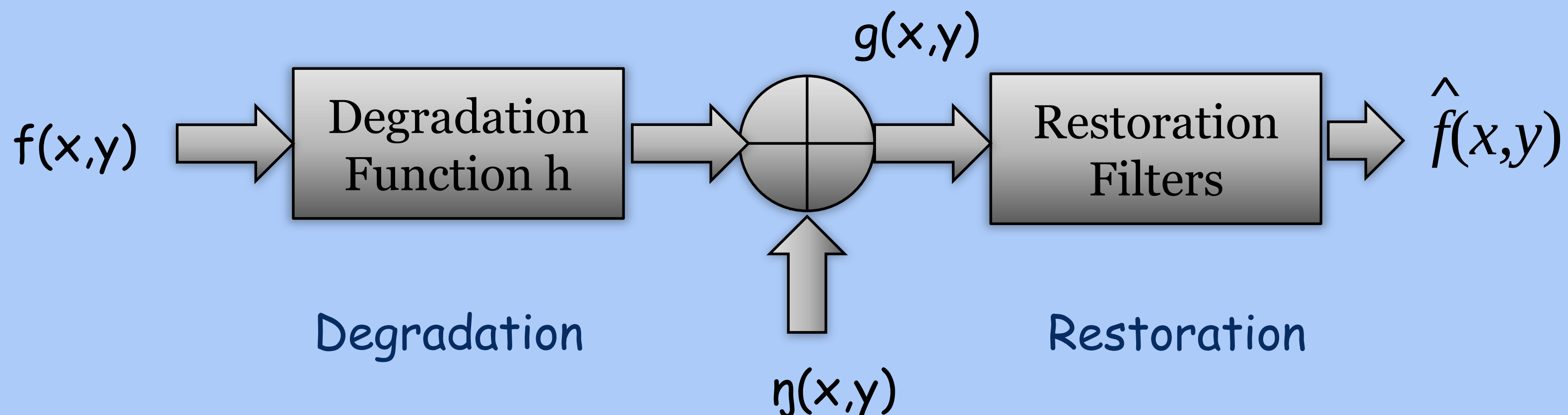
Degradation Model?

- 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: $G=HF+\eta$

Going On….!

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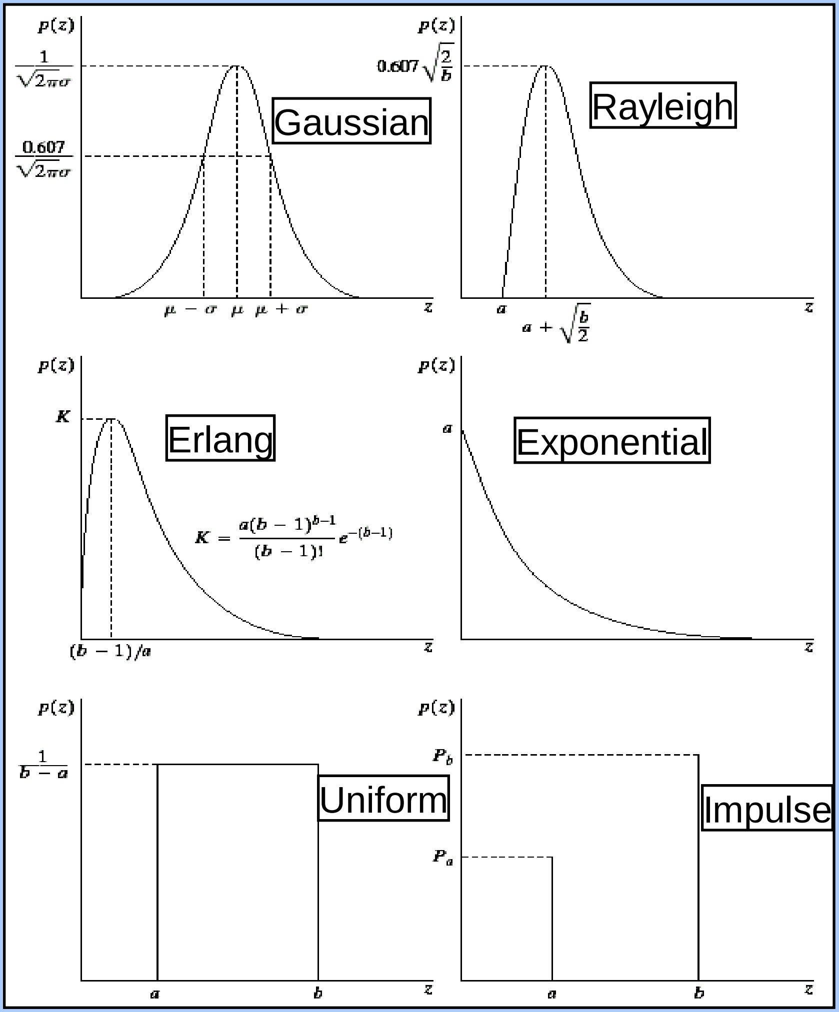
Noise Models and Their PDF

- 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 Effects

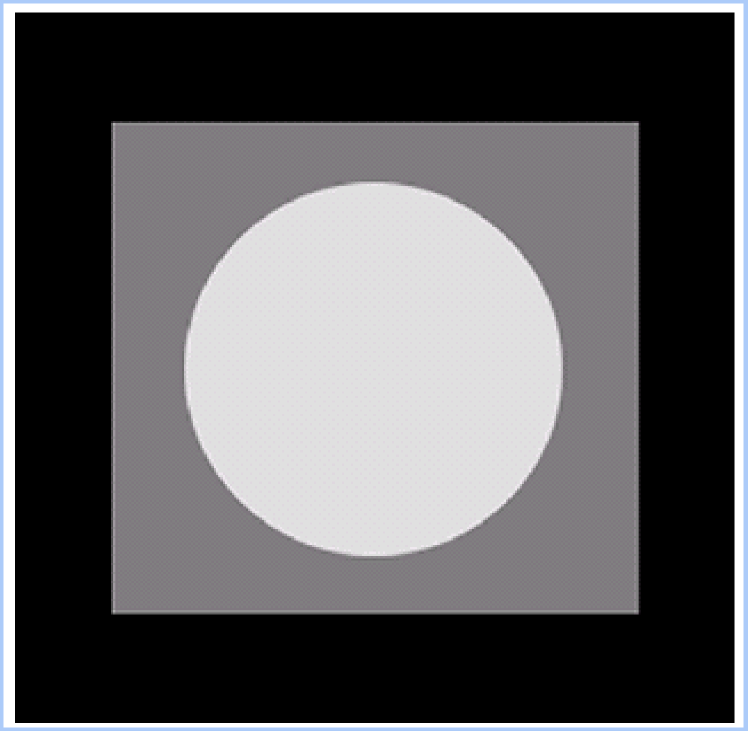
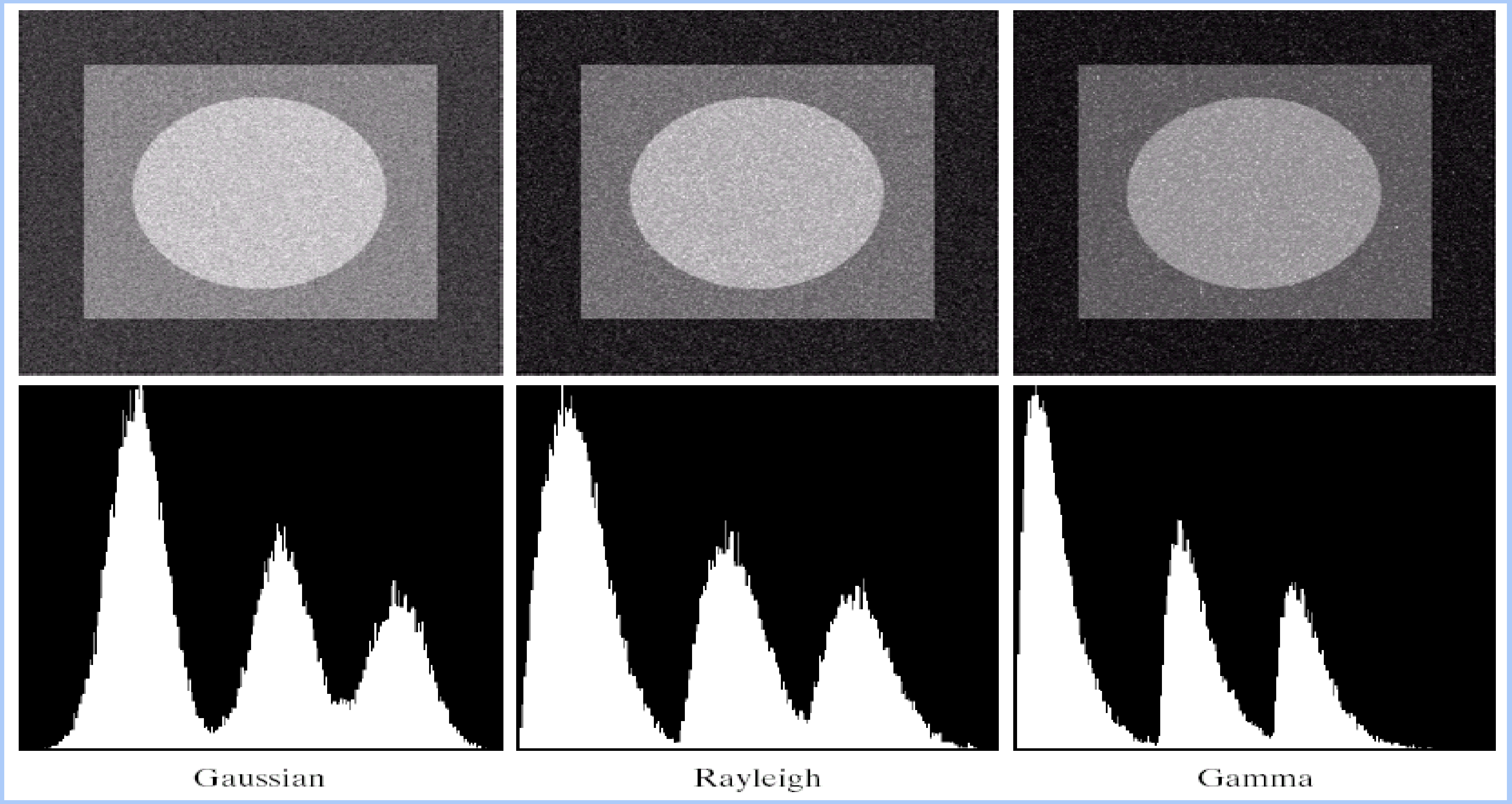


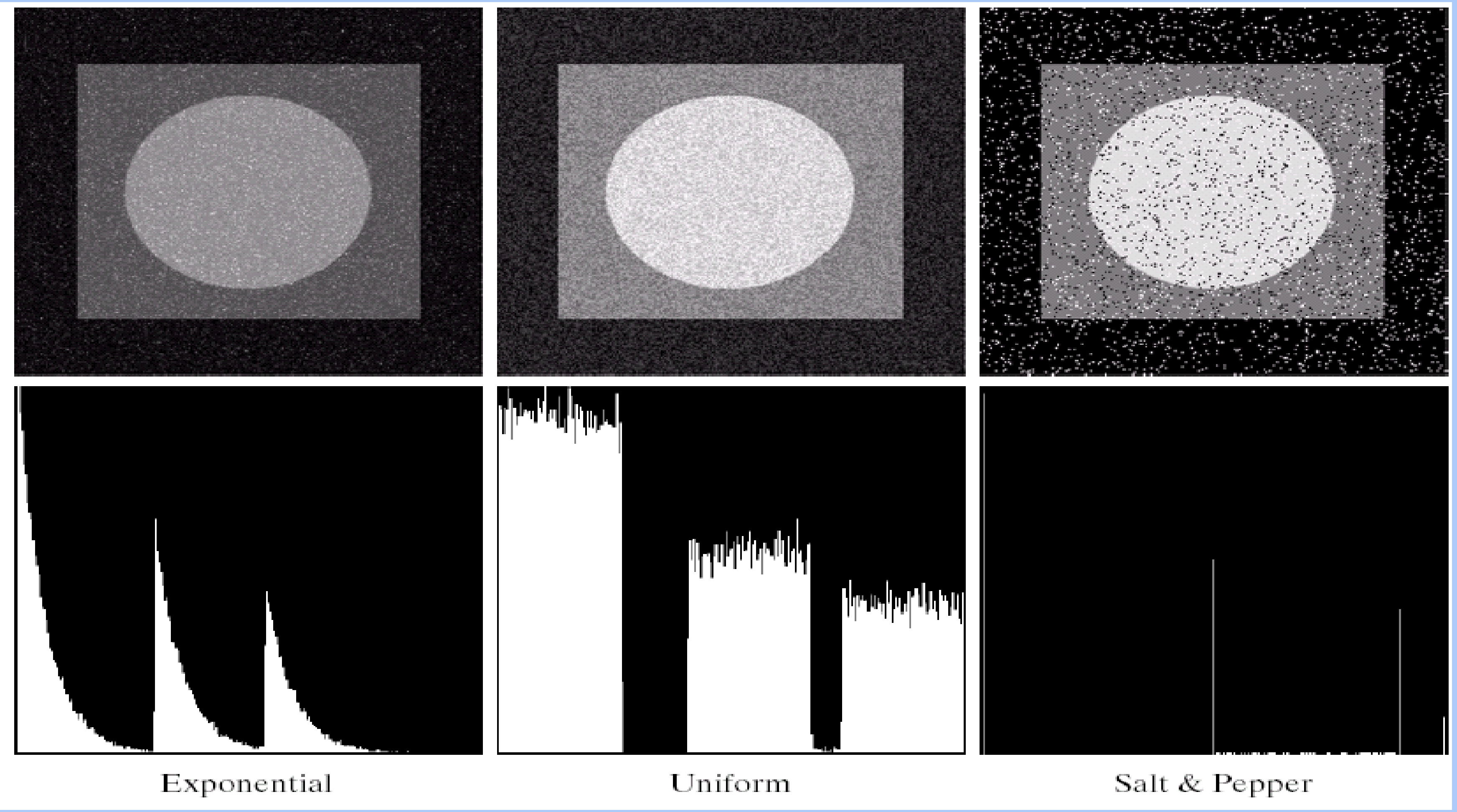
Fig: Original Image

Fig: Original Image histogram

Noise Models Effects contd1…



Noise Models Effects contd2…



Going On….!

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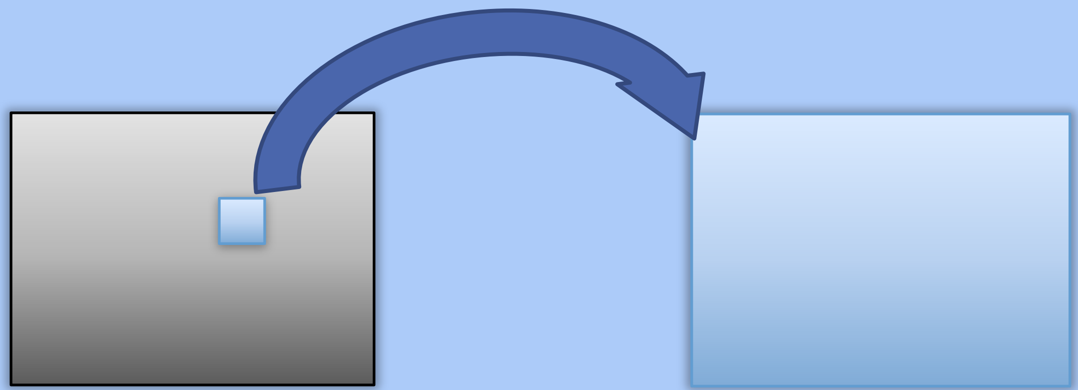
Estimation of Degradation Model.

- Weather the spatial or frequency domain or Matrix, in all cases knowledge of degradation function is important.
- Estimation of H is important in image restoration.
- There are mainly three ways to estimate the H as follows-
  - By Observation
  - By Experimentation.
  - Mathematical Modeling
- After approximation the degradation function, we apply the BLIND CONVOLUTION to restore the original image.

Observation

- No knowledge of degraded function is given.
- Observing on g(x,y), try to estimate the degraded function in the region which have simpler structure.

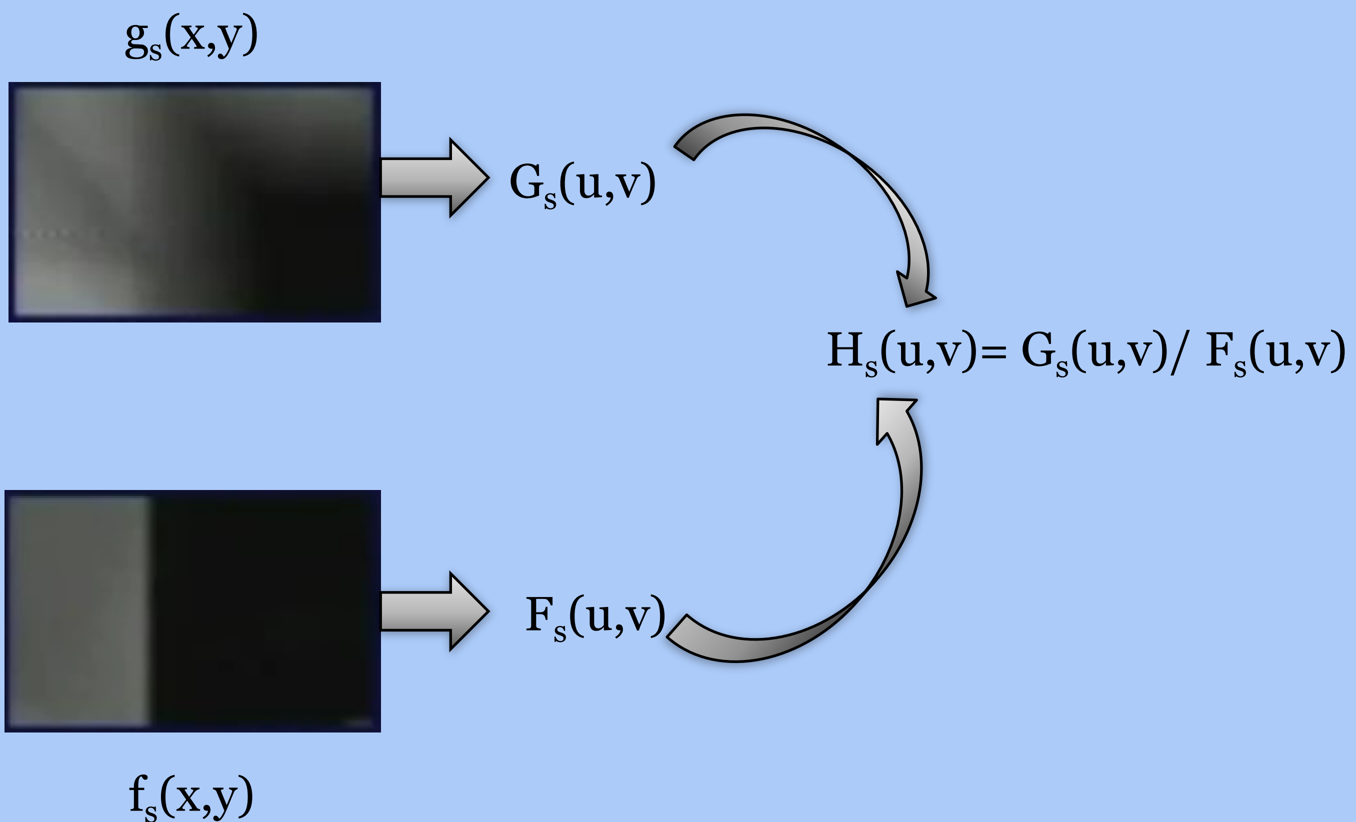


$g_s(x,y) \Leftrightarrow G_s(u,v)$

$f_s(x,y) \Leftrightarrow F_s(u,v)$

$H_s(u,v)= G_s(u,v)/ F_s(u,v)$

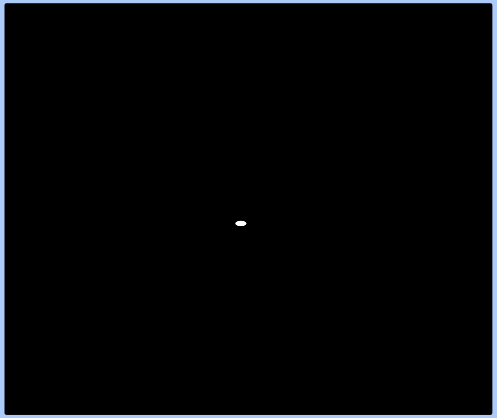
Observation contd…



Experimentation

- Try to imaging set-up similar to original.
  - Impulse response and impulse simulation.
  - Objective to find H which have similar result of degradation as original one.

Impulse



Impulse Response

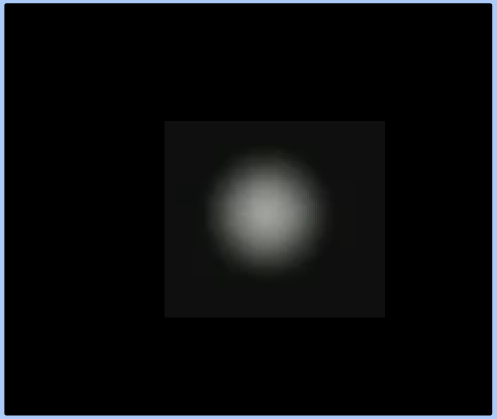


Fig: Impulse Simulation

Experimentation contd…

- Here $f(x,y)$ is impulse.
- $F(u,v)$=>A (a constant).
- $G(u,v)=H(u,v)F(u,v)$.
- $H(u,v)=G(u,v)/A$.
- Objective is training and testing.
- Never testing on training data.

Note: The intensity of impulse is very high, otherwise noise can dominate to impulse.

Mathematical Modeling

- If you have the mathematical model, you have inside the degradation process.
- Atmospheric turbulence can be possible to mapping in mathematical model.
- One e.g. of mathematical model

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

- k gives the nature of turbulence.

Mathematical Modeling contd..

Atmospheric Turbulence blur examples

Fig: Negligible Turbulence

Fig: Severe Turbulence, k=0.0025

Fig: Mid Turbulence, k=0.001

Fig: Low Turbulence, k=0.00025

Present Position

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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.

$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

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:**

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

- 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.

Result of AMF and GMF

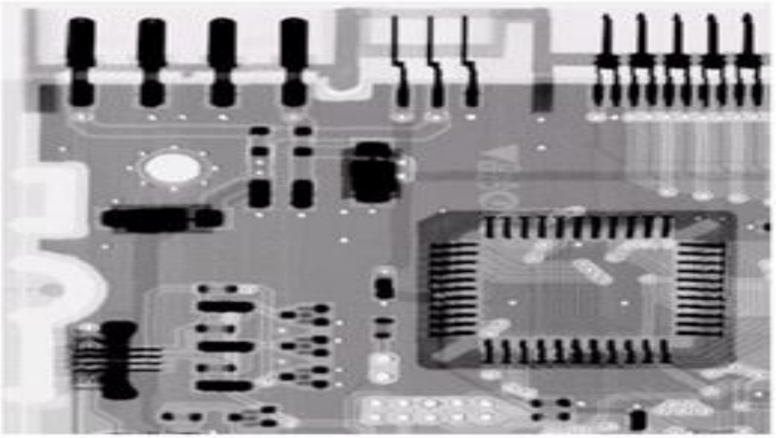


Fig: Original Image

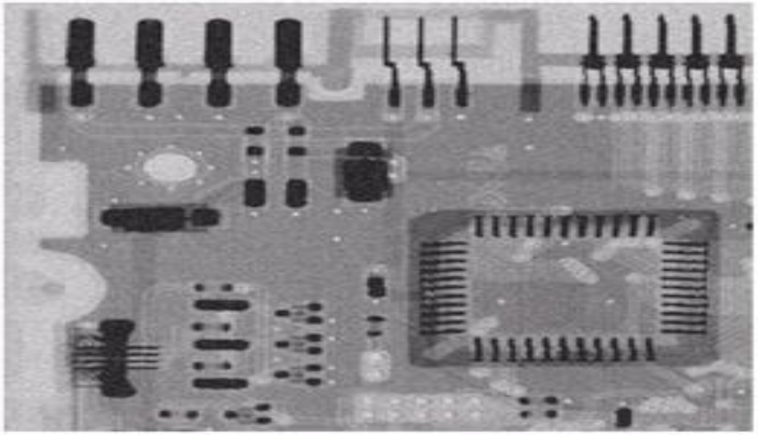


Fig: Gaussian Noise

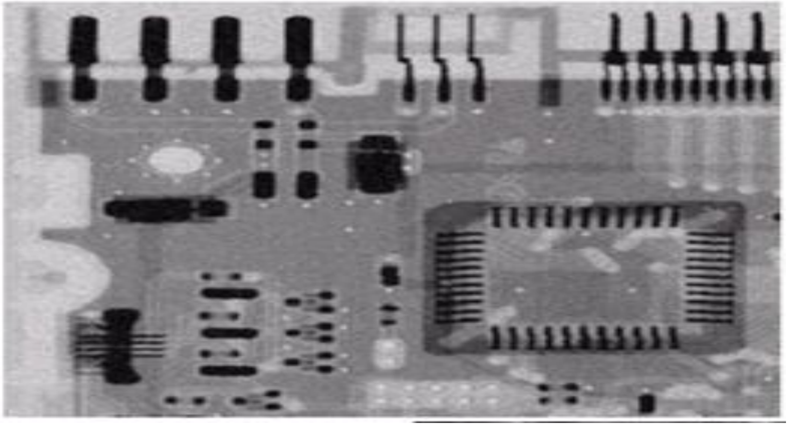


Fig: Result of 3*3 AM

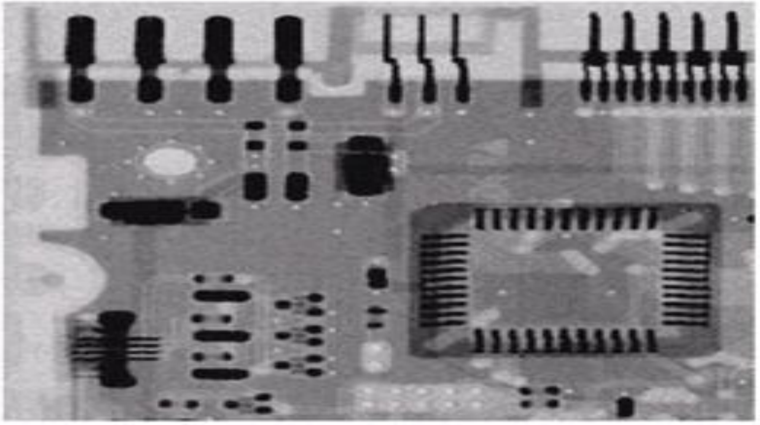


Fig: Result of 3*3 GM

Result of Contra-harmonic Mean Filter

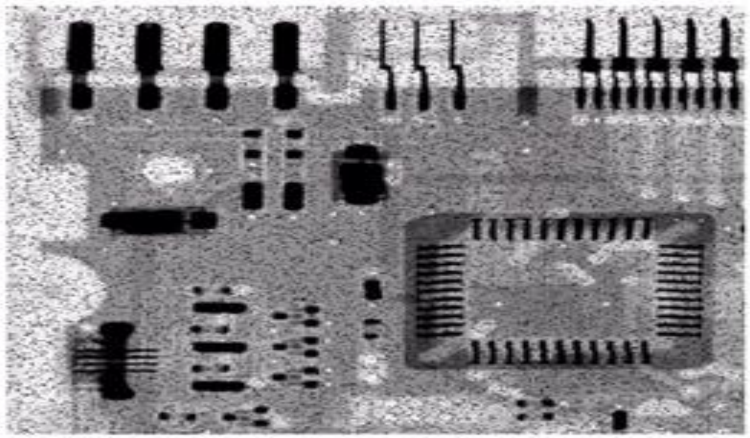


Fig: Original Image with Pepper noise

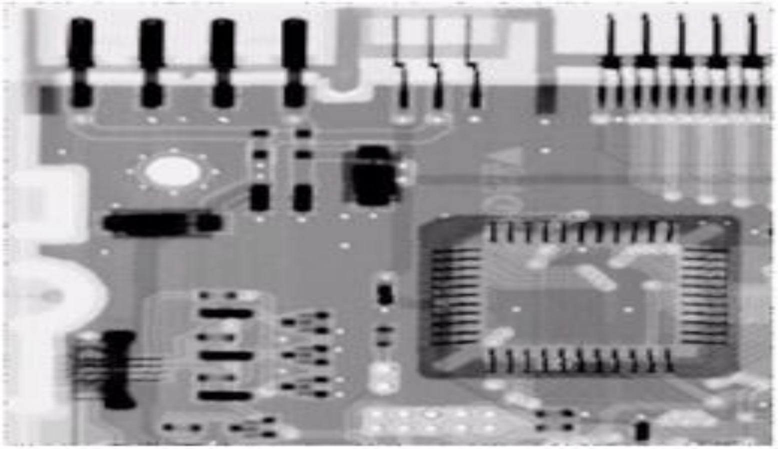


Fig: After filter by 3*3 CHF, Q=1.5

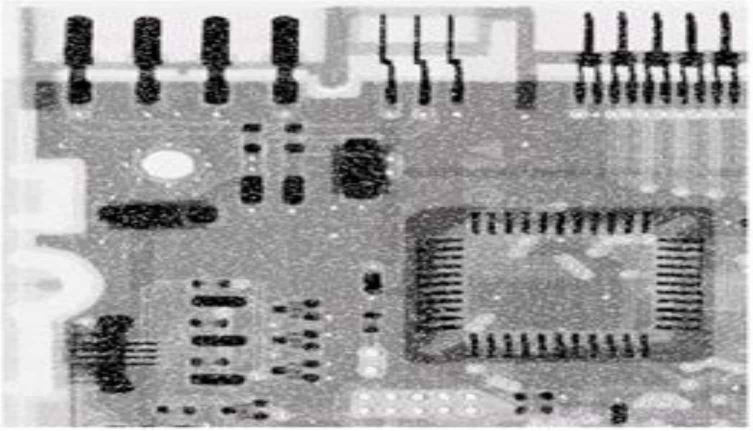


Fig: Original Image with Salt noise

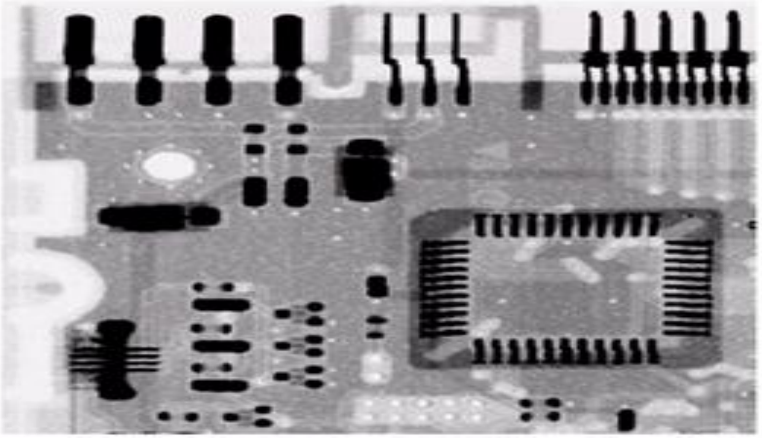
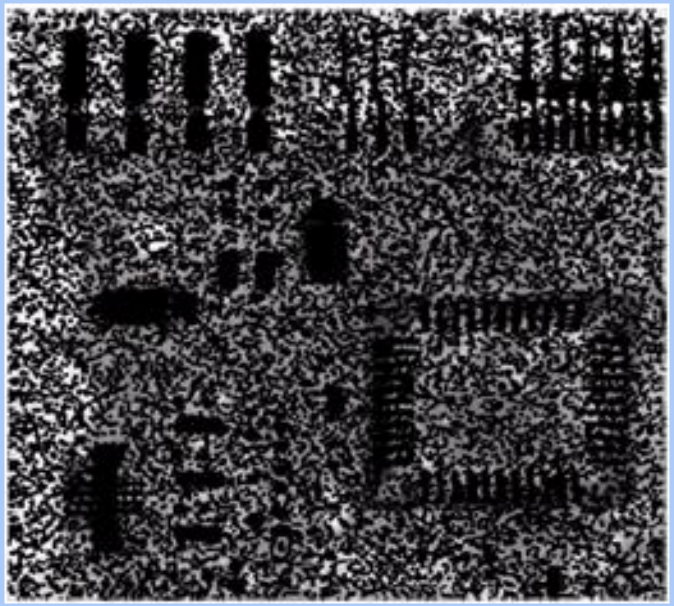
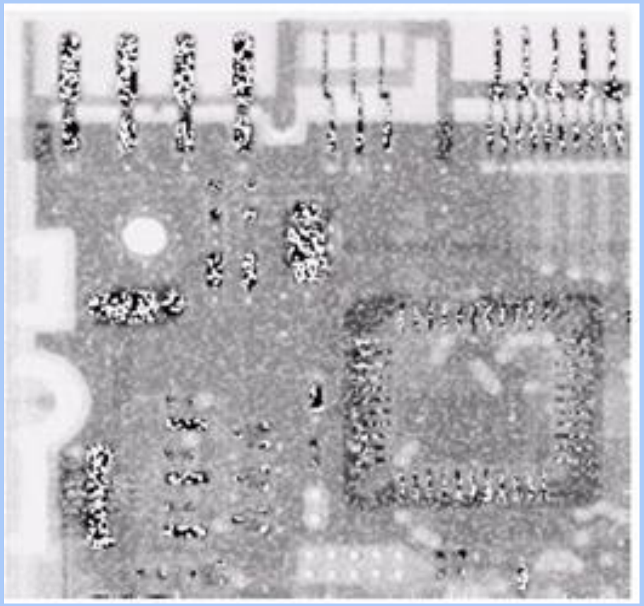


Fig: After filter by 3*3 CHF, Q=-1.5

Beware: Q value in Contra-harmonic Filter

- Choosing the wrong value for Q when using the contra-harmonic filter can have drastic results.





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

Result of Median Filter

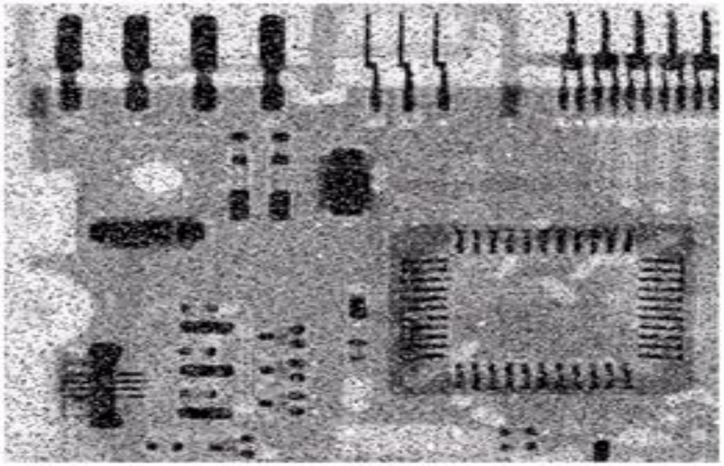


Fig 1: Salt & Pepper noise

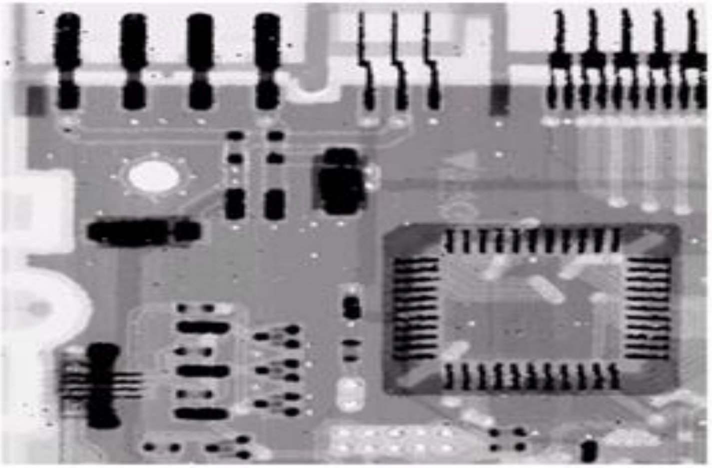


Fig2: Result of 1 pass Med 3*3

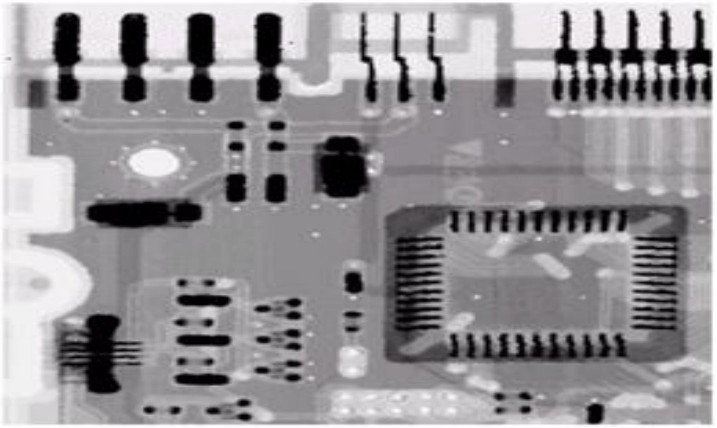


Fig3: Result of 2 pass Med 3*3

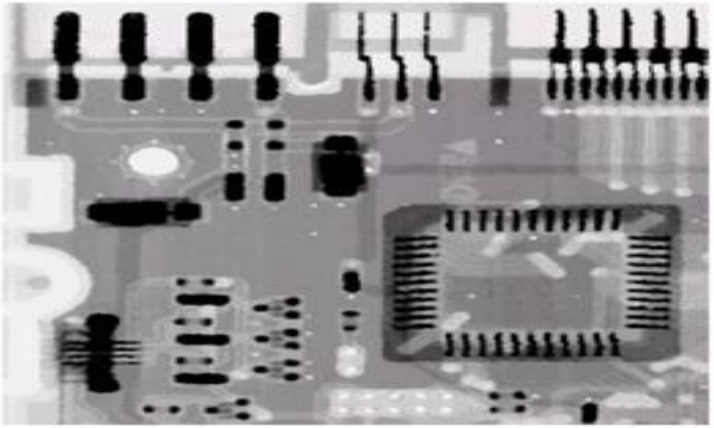


Fig4: Result of 3 pass Med 3*3

Result of Max and Min Filter

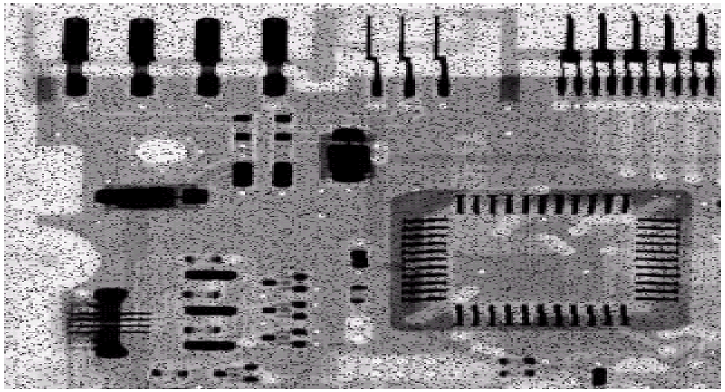


Fig: Corrupted by Pepper Noise

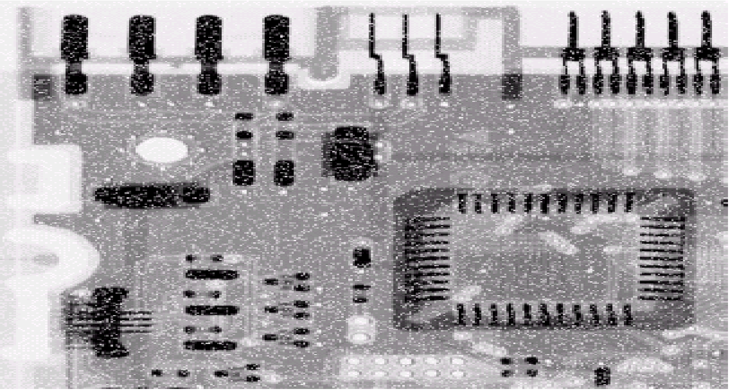


Fig: Corrupted by Salt Noise

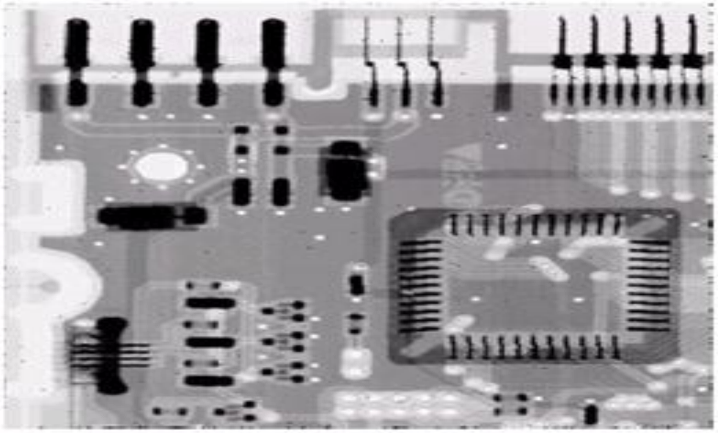


Fig: Filtering Above,3*3 Max Filter

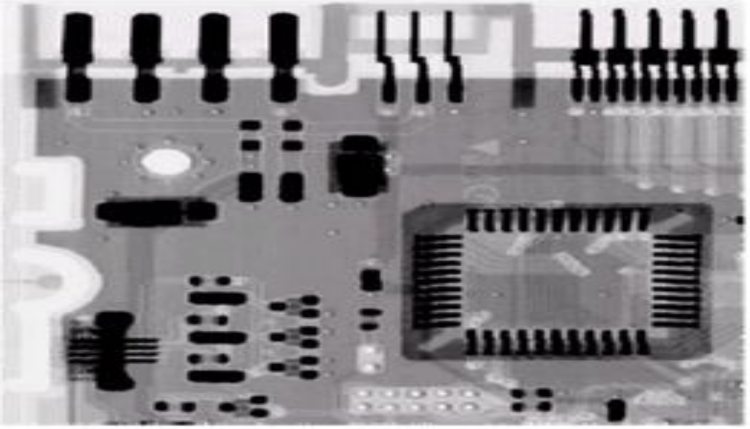
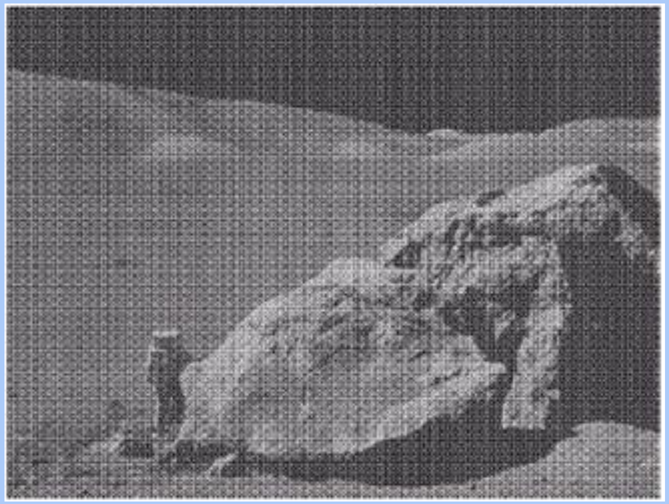


Fig: Filtering Above,3*3 Min Filter

Periodic Noise

- Typically arises due to electrical or electromagnetic interference.
- Gives rise to regular noise patterns in an image
- Frequency domain techniques in the Fourier domain are most effective at removing periodic noise



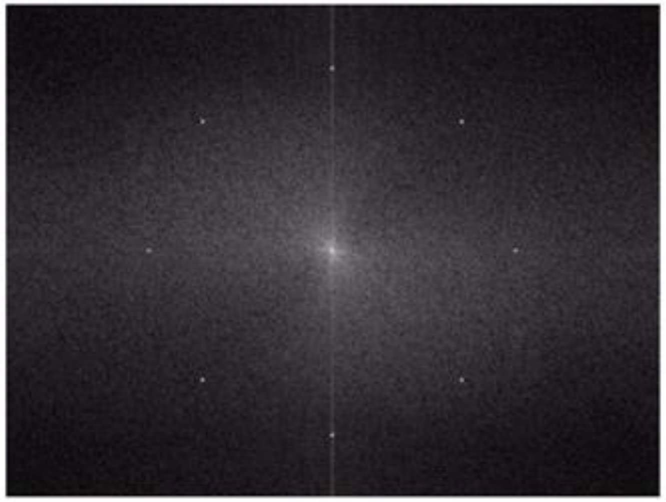


Fig: periodic Noise

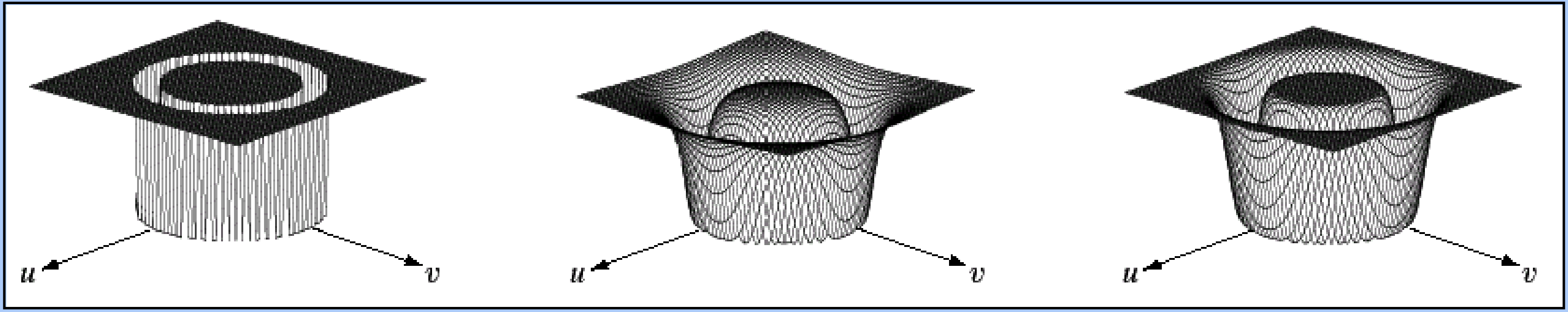
Band Reject Filters

- Removing periodic noise form an image involves removing a particular range of frequencies from that image.
- Band reject filters can be used for this purpose.
- An ideal band reject filter is given as follows:

$$H(u,v) = \begin{cases} 1 & \text{if } D(u,v) < D_0 - \dfrac{W}{2} \\ 0 & \text{if } D_0 - \dfrac{W}{2} \le D(u,v) \le D_0 + \dfrac{W}{2} \\ 1 & \text{if } D(u,v) > D_0 + \dfrac{W}{2} \end{cases}$$

Band Reject Filters contd..

- The ideal band reject filter is shown below, along with Butterworth and Gaussian versions of the filter.



Ideal Band Reject Filter

Butterworth Band Reject Filter (of order 1)

Gaussian Band Reject Filter

Result of Band Reject Filter

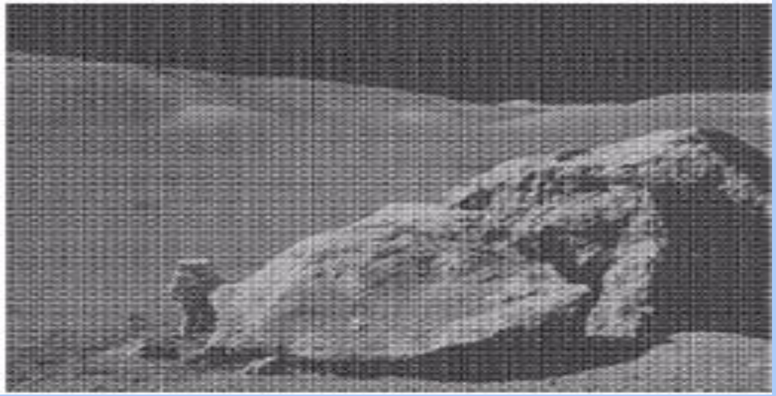


Fig: Corrupted by Sinusoidal Noise

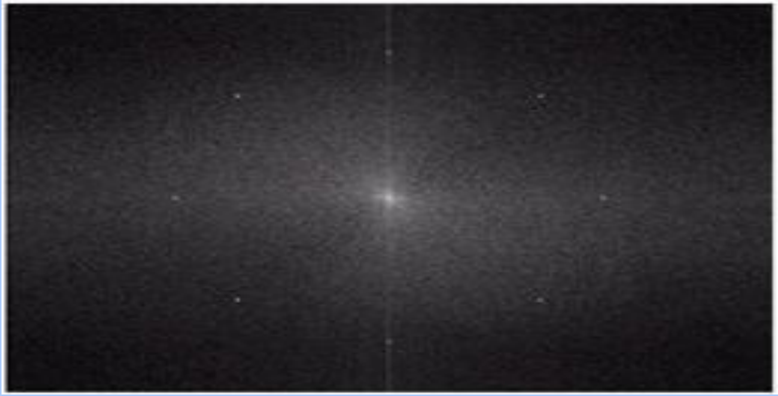


Fig: Fourier spectrum of Corrupted Image

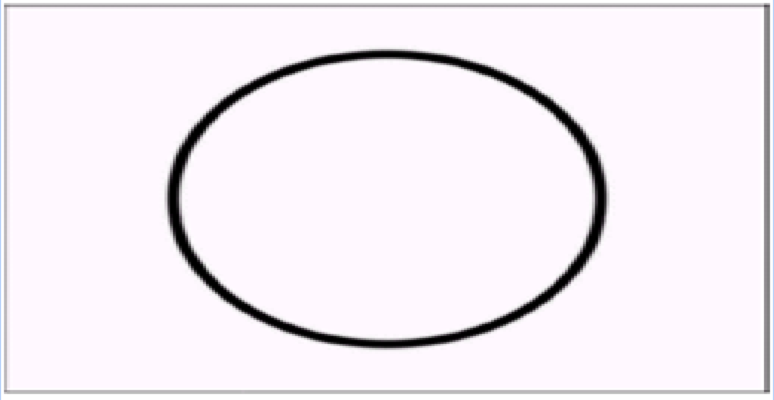


Fig: Butterworth Band Reject Filter

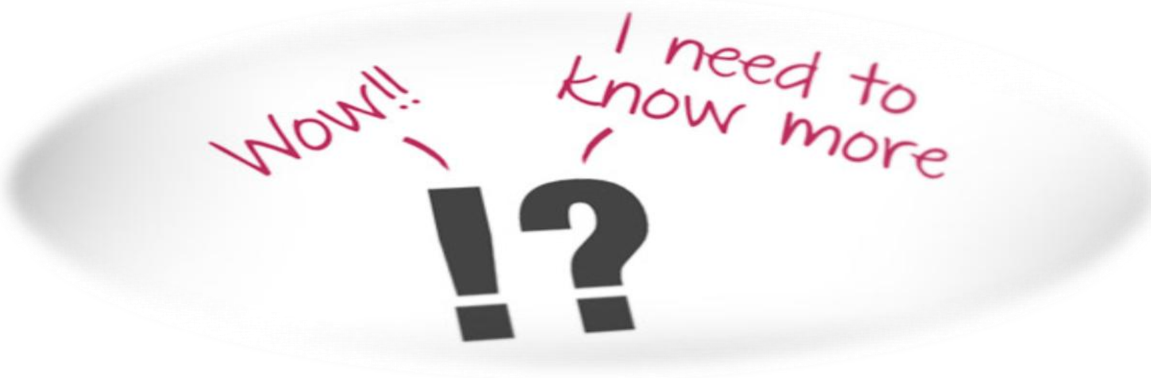
Fig :Filtered image

Conclusions-What we learnt…

- Restore the original image from degraded image, if u have clue about degradation function, is called image restoration.
- The main objective should be estimate the degradation function.
- If you are able to estimate the H, then follow the inverse of degradation process of an image.
- Weather spatial or frequency domain.
  - Spatial domain techniques are particularly useful for removing random noise.
  - Frequency domain techniques are particularly useful for removing periodic noise.

Advanced Image Restoration

- **Adaptive Processing**
  - ✓ Spatial adaptive
  - ✓ Frequency adaptive
- **Nonlinear Processing**
  - ✓ Thresholding, coring …
  - ✓ Iterative restoration
- **Advanced Transformation / Modeling**
  - ✓ Advanced image transforms, e.g., wavelet …
  - ✓ Statistical image modeling
- **Blind Deblurring or Deconvolution**



For advanced Image Restoration (Adaptive Filtering or Nonlinear Filtering etc.), Please referred the book of Gonzalez and Woods, "Digital Image Processing", Pearson Education or any other standard Digital Image Processing Books.

OR

Write me an email : kalyan.acharjya@gmail.com

OR

Lets conclude..!

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Where you start ?

Digital Image Processing !

Popular Image Processing Software Tools

- CVIP tools

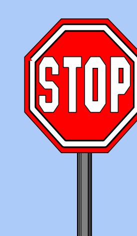
  (Computer Vision and Image Processing tools)
- Intel Open Computer Vision Library
- Microsoft Vision SDL Library
- MATLAB
- KHOROS

Applications of Digital Image Processing?

Applications of Digital Image Processing

- Identification.
- Computer Vision or Robot vision.
- Steganography.
- Image Enhancement.
- Image Analysis in Medical.
- Morphological Image Analysis.
- Space Image Analysis.
- Bottling and IC Industry……….*etc.*

Almost Everywhere Image Processing is going on…….!



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THANK YOU
FOR YOUR
ATTENTION