DIGITAL IMAGE PROCESSING-1

Unit 4: Lecture 41

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Unit 4: Image Filtering and Restoration

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Last Session

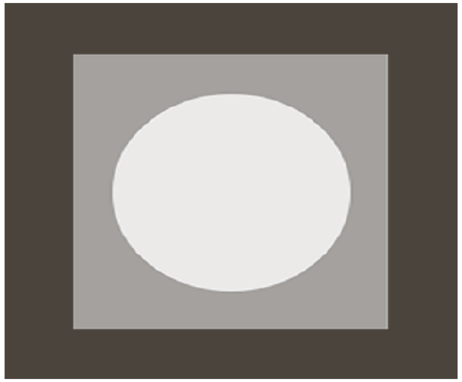
- Introduction to Image Restoration
- Degradation model
- Noise Models

This Session

- Estimation of noise parameters
- Restoration in the presence of Noise only

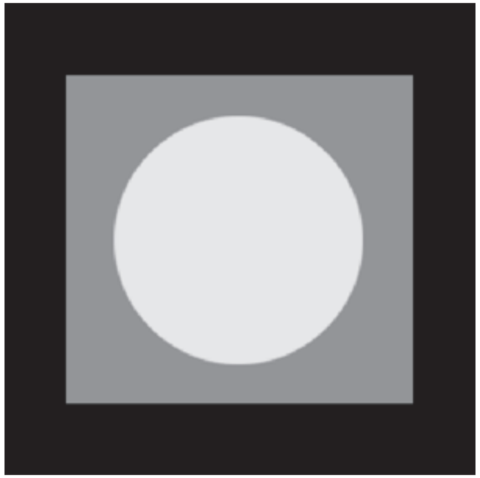
Noise Corruption: Noisy Images and their Histograms

- Test pattern used for illustrating the noise models

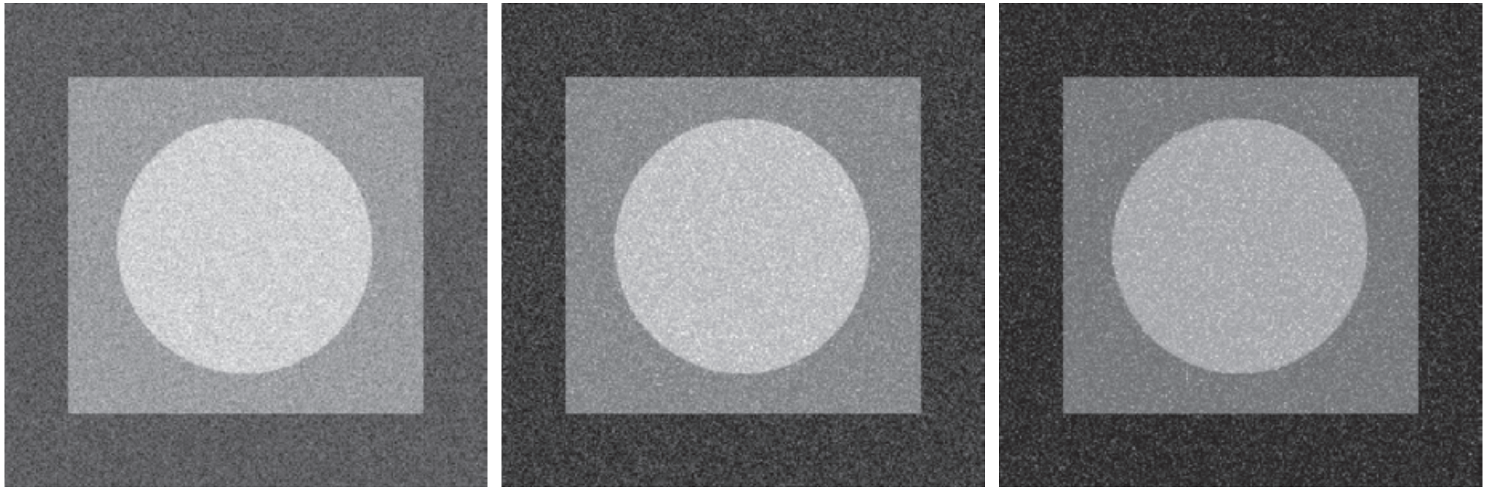


- This is a suitable pattern to use because it is composed of simple, constant areas that span the grayscale from black to near white in only three increments.
- This facilitates visual analysis of the characteristics of the various noise components added to an image.

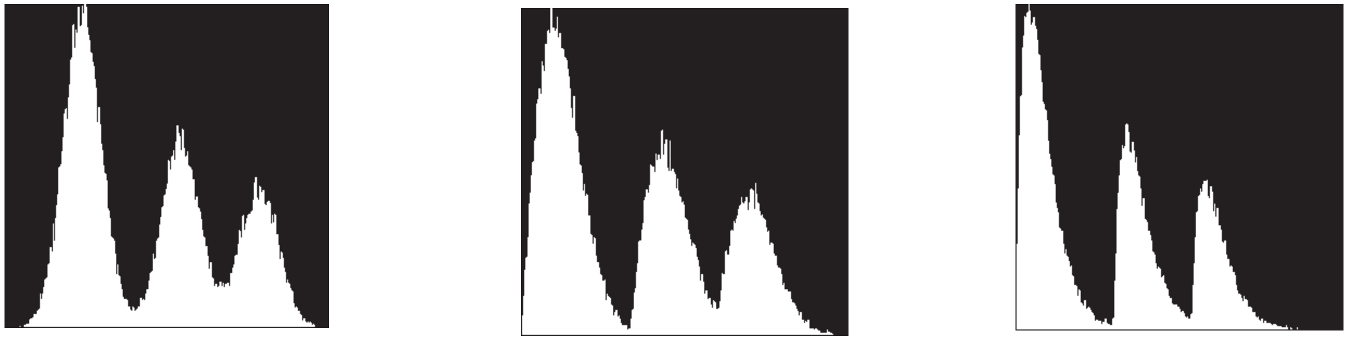
Noisy Images and their Histograms



Test pattern

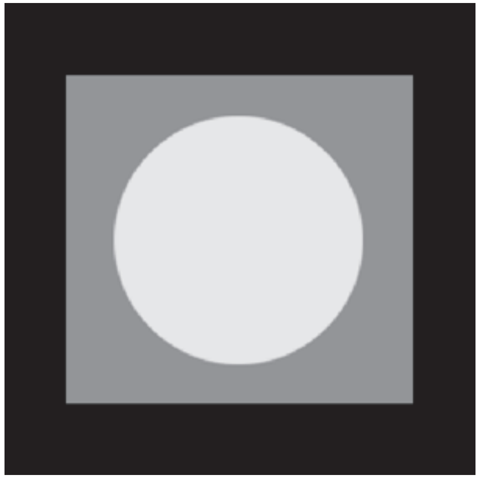


Images resulting from adding Gaussian, Rayleigh, and Erlang noise to the test image

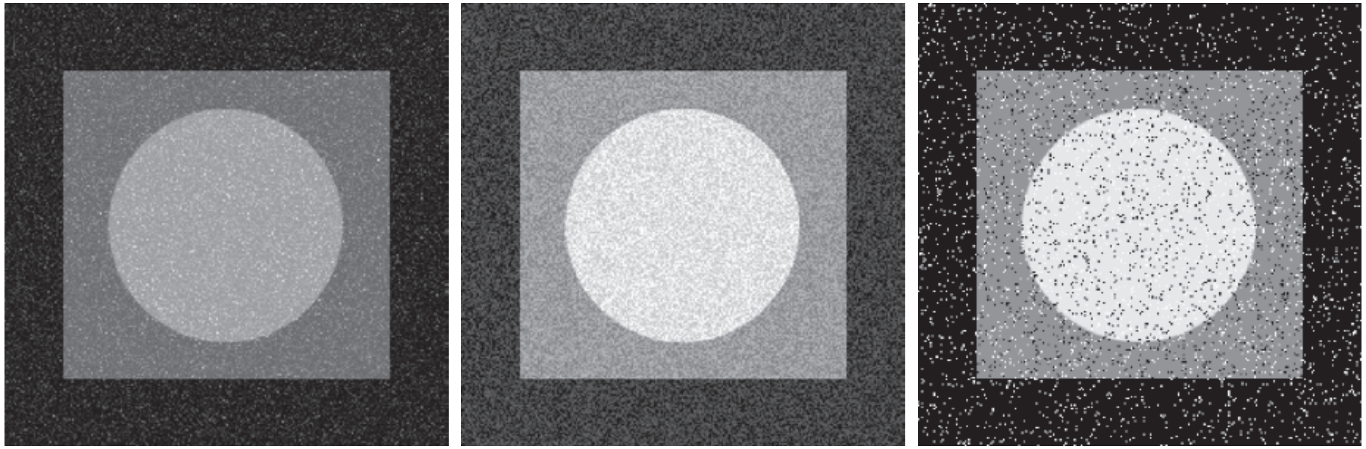


Corresponding histograms

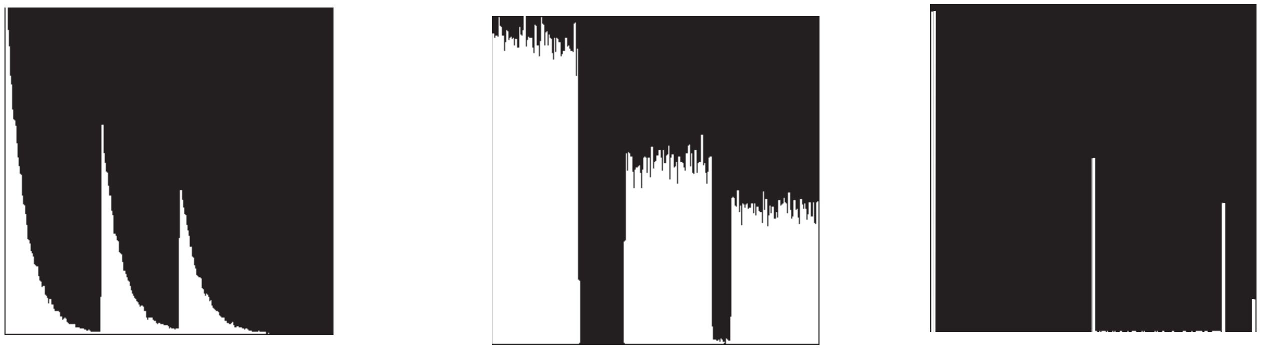
Noisy Images and their Histograms



Test pattern



Images resulting from adding exponential, uniform, and salt-and-pepper noise to the test image



Corresponding histograms

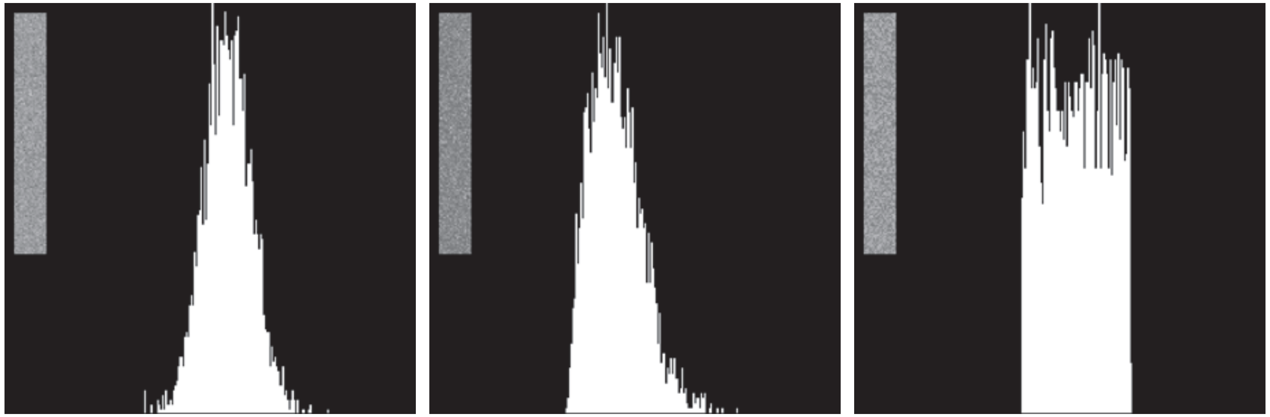
Estimation of Noise Parameters

- The parameters of periodic noise typically are estimated by inspection of the Fourier spectrum.
- Periodic noise tends to produce frequency spikes that often can be detected even by visual analysis
- Another approach is to attempt to infer the periodicity of noise components directly from the image, but this is possible only in simplistic cases.
- Automated analysis is possible in situations in which the noise spikes are either exceptionally pronounced, or when knowledge is available about the general location of the frequency components of the interference

Estimation of Noise Parameters

- The parameters of noise PDFs may be known partially from sensor specifications, but it is often necessary to estimate them for a particular imaging arrangement.
- If the imaging system is available, one simple way to study the characteristics of system noise is to capture a set of “flat” images.
  - For example, in the case of an optical sensor, this is as simple as imaging a solid gray board that is illuminated uniformly.
- The resulting images typically are good indicators of system noise.
- **When only images already generated by a sensor are available, it is often possible to estimate the parameters of the PDF from small patches of reasonably constant background intensity.**

Estimation of Noise Parameters



Histograms computed using small strips (shown as inserts) from
(a) the Gaussian, (b) the Rayleigh, and (c) the uniform noisy images

We see that the shapes of these histograms correspond quite closely to the shapes of the corresponding noise histograms. Heights are different due to scaling

Estimation of Noise Parameters

- The simplest use of the data from the image strips is for calculating the mean and variance of intensity levels.
- In most cases, only mean and variance are to be estimated
  - Others can be obtained from the estimated mean and variance
- Consider a strip (subimage) denoted by S, and let $p_S(z_i)$, $i = 0, 1, 2, \ldots, L-1$, denote the probability estimates (normalized histogram values) of the intensities of the pixels in S, where L is the number of possible intensities in the entire image

Estimation of Noise Parameters

- Estimate the mean and variance of the pixel values in S as follows:
  - Mean of z_i
$$\bar{z} = \sum_{i=0}^{L-1} z_i p_S(z_i)$$
  - Variance
$$\sigma^2 = \sum_{i=0}^{L-1} (z_i - \bar{z})^2 p_S(z_i)$$

For Gaussian noise: μ, σ
Others: a, b

i= 0,1, 2,…..L-1

- The shape of the histogram identifies the closest PDF match.
- If the shape is approximately Gaussian, then the mean and variance are all we need because the Gaussian PDF is specified completely by these two parameters.
- For the other shapes discussed earlier, we use the mean and variance to solve for the parameters *a* and *b*.

Restoration in the Presence of Noise Only

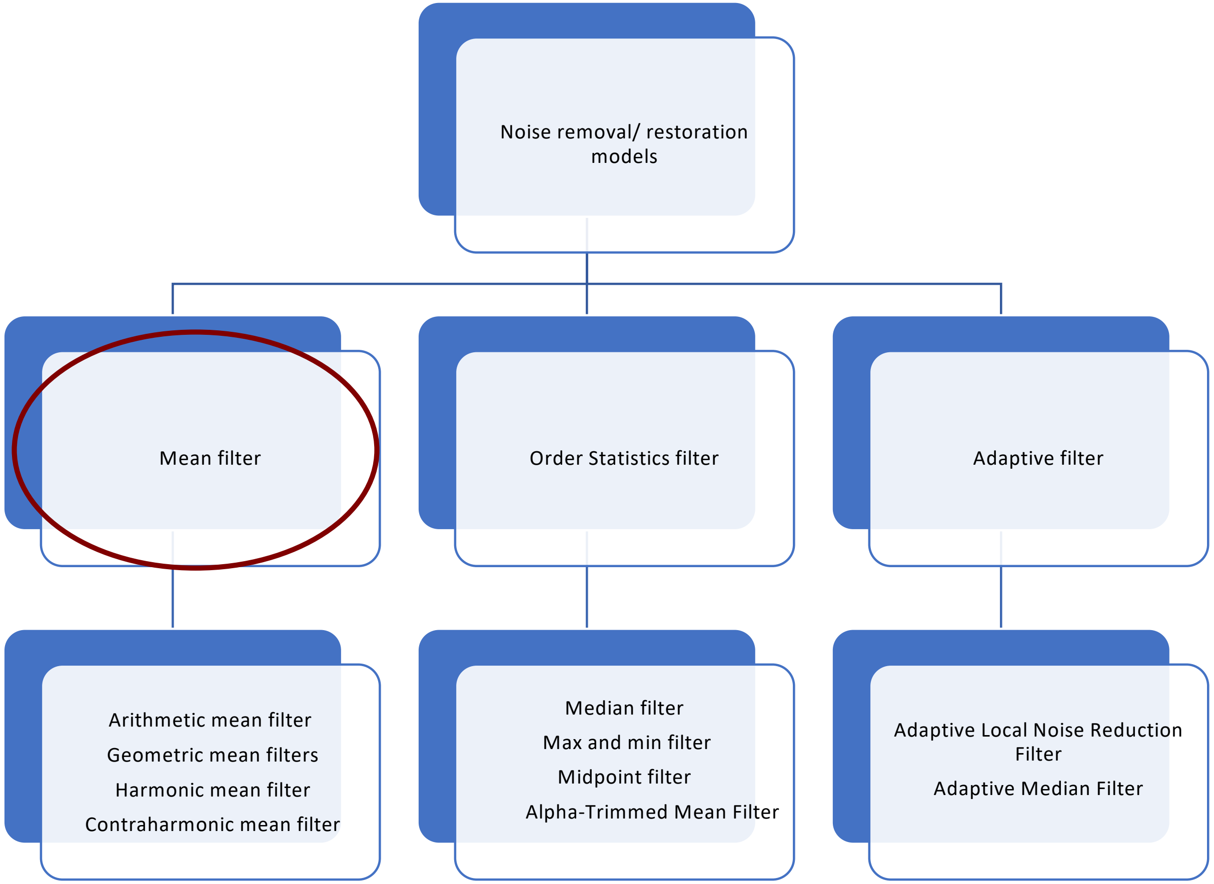
- In the presence of noise only:
  - Making H an identity operator and assuming degradation is only due to additive noise

  In spatial domain: $g(x,y) = f(x,y) + n(x,y)$

  In frequency domain: $G(u,v) = F(u,v) + N(u,v)$

- Spatial filtering is the method of choice in situations when only additive random noise is present
- In case of periodic noise it is usually possible to estimate N(u,v) from spectrum of G(u,v).
  - Then N(u,v) is subtracted (filtered) from G(u,v) to obtain an estimate of original image

Restoration in the Presence of Noise Only (Spatial Filtering)



Restoration in the Presence of Noise Only: Mean Filter

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

- Arithmetic mean filter
  - g(x,y) is the corrupted image
  - $S_{x,y}$ is the mask

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

- Geometric mean filters
  - Tends to preserve more details

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

- Harmonic mean filter
  - Works well for salt noise but fails for pepper noise

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

- Contraharmonic mean filter
  - Suited for salt / pepper noise
  - Q: order of the filter
  - Positive Q works for pepper noise
  - Negative Q works for salt noise
  - Q=0 ➔ arithmetic mean filter
  - Q=-1 ➔ harmonic mean filter

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

Examples

- Arithmetic Mean filter

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

30	10	20
10	250	25
20	25	30

(x, y)

X	X	X
X	47	X
X	X	X

$$mean\{g(s,t)\} = {}^{1}/_{9}[\,30+10+20+10+250+25+20+25+30] = 46.6 \approx 47$$

Examples

- Geometric mean filter

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

30	10	20
10	250	25
20	25	30

(x, y)

X	X	X
X	26	X
X	X	X

- Geometric mean of g(s,t)

$$g(s,t) = \left(30\times10\times20\times10\times250\times25\times20\times25\times30\right)^{1/3\times3}$$

$$= 26.1 \approx 26$$

Examples

- Harmonic filter

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

(x, y)

30	10	20
10	250	25
20	25	30

$\rightarrow$

X	X	X
X	20	X
X	X	X

$$\hat{f}(x,y) = \frac{9}{1/30+1/10+1/20+1/10+1/250+1/25+1/20+1/25+1/30}$$

$$= 19.97 \approx 20$$

Examples

- Contra - Harmonic filter (for salt noise)

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

(x, y)

30	10	20
10	0	25
20	25	30

→

X	X	X
X	25	X
X	X	X

There is pepper noise so Let Q=1.5(positive)

Then

$$\hat{f}(x,y)=\frac{30^{2.5}+10^{2.5}+20^{2.5}+10^{2.5}+25^{2.5}+20^{2.5}+25^{2.5}+30^{2.5}}{30^{1.5}+10^{1.5}+20^{1.5}+10^{1.5}+25^{1.5}+20^{1.5}+25^{1.5}+30^{1.5}}$$

=24.75=25

Examples

- Contra-Harmonic filter for pepper noise

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

(x, y)

30	10	20
10	250	25
20	25	30

$\longrightarrow$

X	X	X
X	17	X
X	X	X

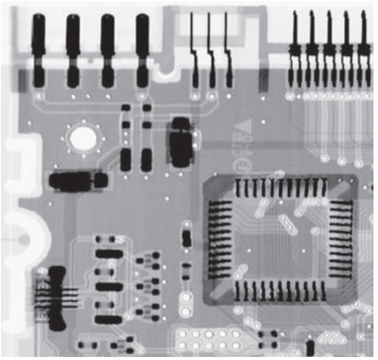
There is salt noise so Let Q= -1.5(negative)

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

$$= \frac{30^{-0.5}+10^{-0.5}+20^{-0.5}+10^{-0.5}+250^{-0.5}+25^{-0.5}+20^{-0.5}+25^{-0.5}+30^{-0.5}}{30^{-1.5}+10^{-1.5}+20^{-1.5}+10^{-1.5}+250^{-1.5}+25^{-1.5}+20^{-1.5}+25^{-1.5}+30^{-1.5}}$$

= 16.66=17

Examples



X-ray image of circuit board.

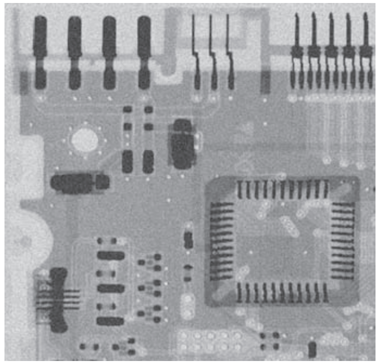
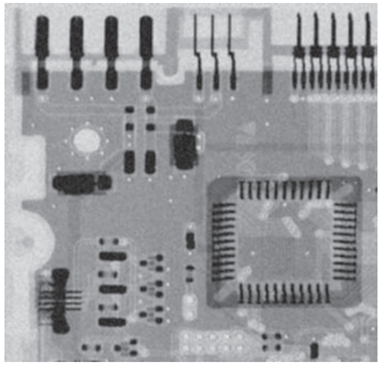
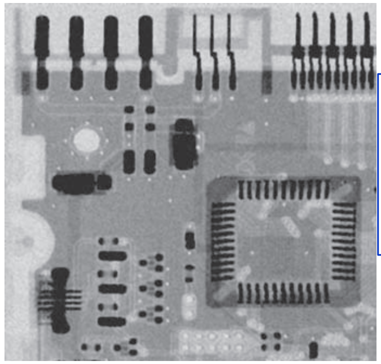


Image corrupted by additive Gaussian noise.



Result of filtering with an arithmetic mean filter of size 3 x 3

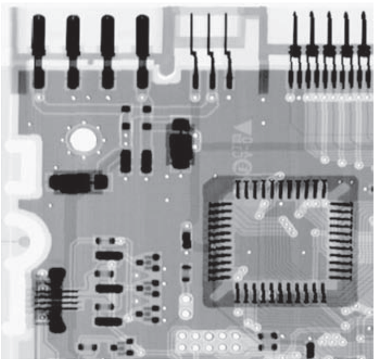
The noise was smoothed out, but at the cost of significant blurring.



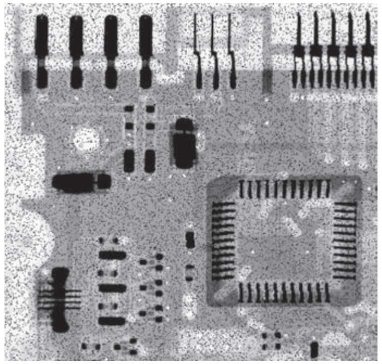
Similar to arithmetic filter. Only degree of blurring is different

Result of filtering with a geometric mean filter of the same size.

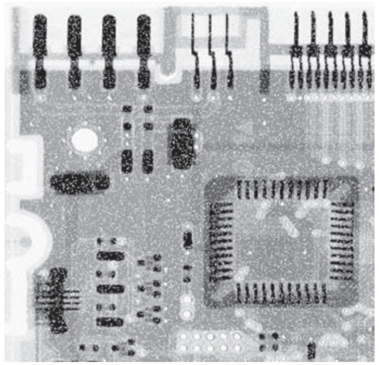
Examples



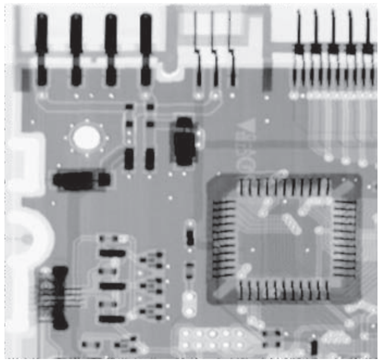
X-ray image of circuit board.



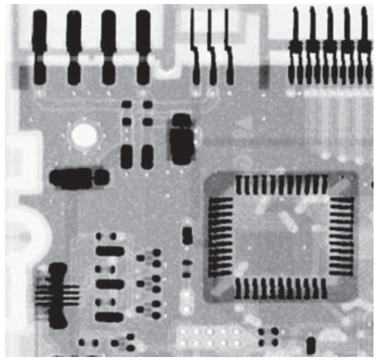
(a)Image corrupted by pepper noise with a probability of 0.1.



(b) Image corrupted by salt noise with the same probability.

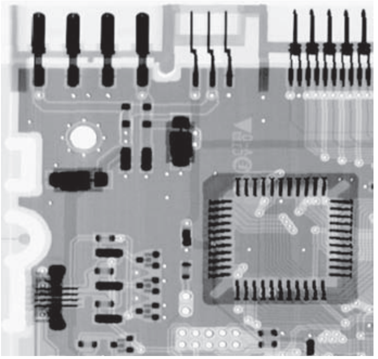


Result of filtering (a) with a 3x3 contra- harmonic filter $Q = 1.5$.

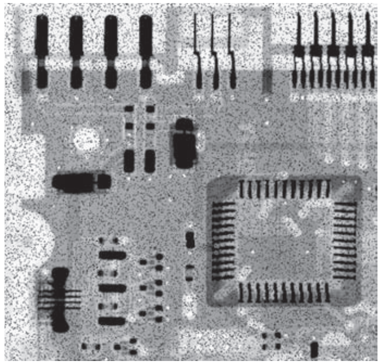


Result of filtering (b) with $Q = -1.5$.

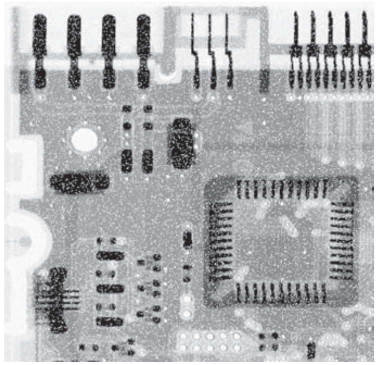
Examples



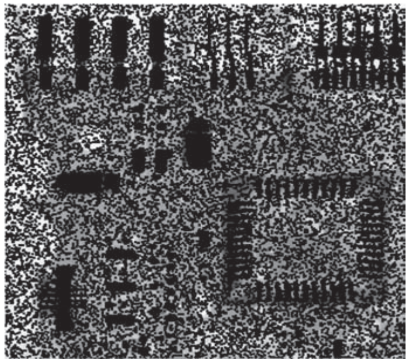
X-ray image of circuit board.

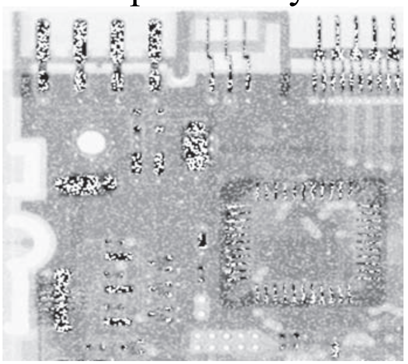


(a)Image corrupted by pepper noise with a probability of 0.1.



(b) Image corrupted by salt noise with the same probability.





(b) Result of filtering using $Q = 1.5$.

Results of selecting the wrong sign in contraharmonic filtering (a) Result of filtering (a) in previous example with a contraharmonic filter of size 3×3 and $Q = -1.5$.

Next Session

- Image Restoration in presence of degradation

THANK YOU

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