DIGITAL IMAGE PROCESSING

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1. IMAGE RESTORATION AND IMAGE DEGRADATION

1. IMAGE RESTORATION

- Image restoration is task of recovering or reconstructing an image from its degraded version.

- The restoration technique models the degradation process and applies the inverse process to obtain the original from the degraded

- It differs from image enhancement–which does not fully account for the nature of the degradation. Image enhancement is largely a subjective process while image restoration is an objective process.

1.1 TYPES OF DEGRADATION

- original

- optical blur

- motion blur

- spatial quantization (discrete pixels)

- additive intensity noise

1.2 CAUSES OF DEGRADATION

- Movements during the image capture process, by the camera or, when long exposure times are used, by the subject.

- Out-of-focus optics, use of a wide-angle lens, atmospheric turbulence, or a short exposure time, which reduced the number of photons captured.

- Scattered light distortion in confocal microscopy

1.4 IMAGE RESTORATION AND IMAGE DEGRADATION MODEL

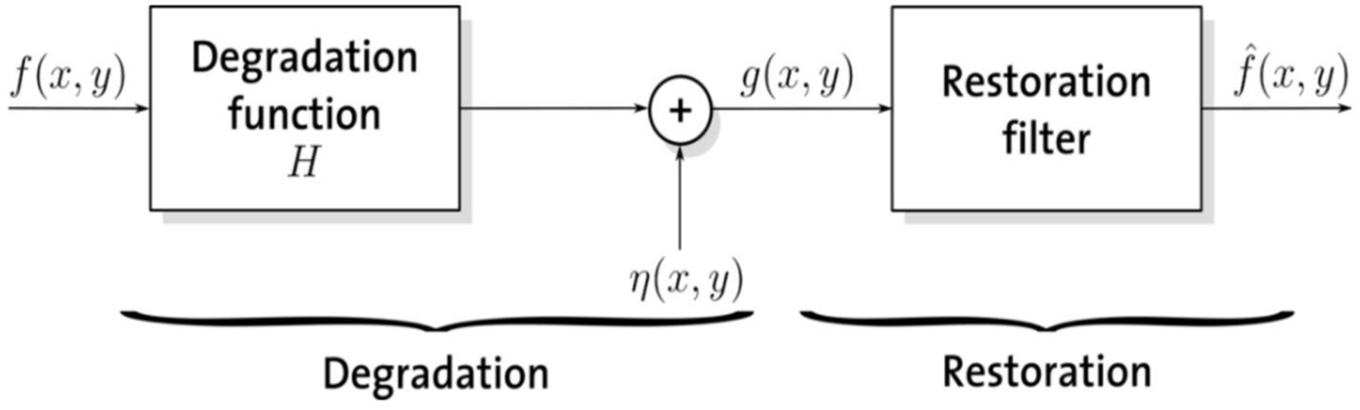


Fig: Image Restoration and Image Degradation Model

OBJECTIVES OF IMAGE RESTORATION

The objective of image restoration is to obtain an estimate of the original image ***f*(x,y)** . Here, by some knowledge of **H** and **η(x,y)** , we find the appropriate restoration filters, so that output image **$\hat{f}$(x,y)** is as close as original image ***f*(x,y)** as possible since it is practically not possible (or very difficult) to completely (or exactly) restore the original image.

TERMINOLOGY:

g(x,y) = degraded image

***f*(x,y)** = input or original image

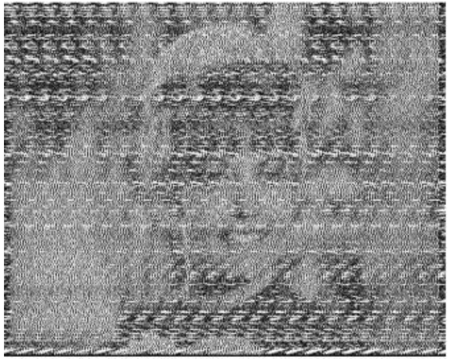
$\hat{f}$ (x,y)= recovered or restored image

η(x,y) = additive noise term

1.5 EXAMPLE OF DEGRADATION AND RESTORATION

(A) Image Degraded by Blur

(B) Image Restored Using the Pseudo Inverse Filter



(C) Image in (A), Quantized with 256 Levels, after Application of the Pseudo-Inverse Filter

(D) Image in (A), Quantized with 256 Levels, after Application of the Wiener Filter

2. NOISE MODELS

2.1 WHAT IS NOISE ?

Noise tells unwanted information in digital images. Noise produces undesirable effects such as artifacts, unrealistic edges, unseen lines, corners, blurred objects and disturbs background scenes. To reduce these undesirable effects.

2.2 NOISE TYPES

1. GAUSSIAN NOISE MODEL Most common type
2. WHITE NOISE
3. BROWNIAN NOISE (FRACTAL NOISE)
4. IMPULSE VALUED NOISE (SALT AND PEPPER NOISE)
5. PERIODIC NOISE
6. QUANTIZATION NOISE
7. SPECKLE NOISE
8. PHOTON NOISE (POISSON NOISE)
9. POISSON - GAUSSIAN NOISE
10. STRUCTURED NOISE
11. GAMMA NOISE
12. RAYLEIGH NOISE

2.2.1 GAUSSIAN NOISE

- It is also called as electronic noise because it arises in amplifiers or detectors.

- Gaussian noise generally disturbs the gray values in digital images. That is why Gaussian noise model essentially designed and characteristics by its PDF or normalizes histogram with respect to gray value. This is given as

$$P(g) = \sqrt{\frac{1}{2\pi\sigma^2}}e^{-\frac{(g-\mu)^2}{2\sigma^2}}$$

Where **g** = gray value, σ = standard deviation and **μ** = mean.

Generally Gaussian noise mathematical model represents the correct approximation of real world scenarios. In this noise model, the mean value is zero, variance is 0.1 and 256 gray levels in terms of its PDF, which is shown in Fig.

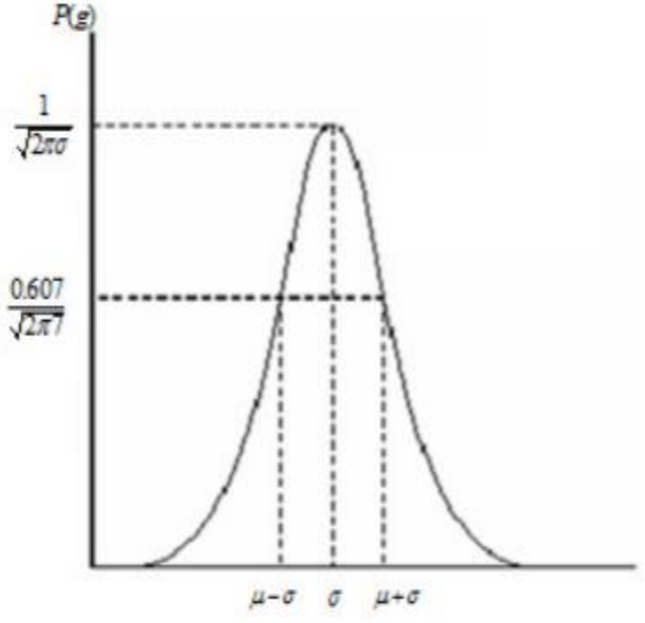
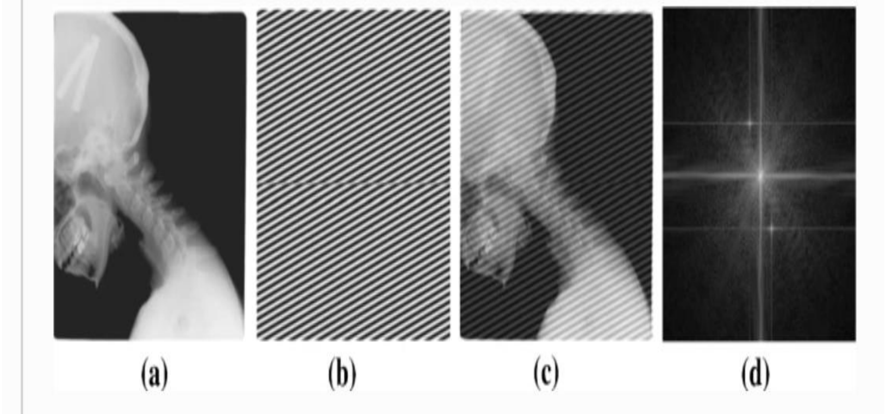


Figure 1 PDF of Gaussian noise

2.2.2 PERIODIC NOISE

This noise is generated from electronics interferences, especially in power signal during image acquisition. This noise has special characteristics like spatially dependent and sinusoidal in nature at multiples of specific frequency. It appears in form of conjugate spots in frequency domain. It can be conveniently removed by using a narrow band reject filter or notch filter.



X-Ray image corrupted by periodic noise.
a Original image,
b noise pattern,
c noisy image in spatial domain,
d noisy image in frequency domain

2.2.3 SPECKLE NOISE

This noise is multiplicative noise. Their appearance is seen in coherent imaging system such as laser, radar and acoustics etc, Speckle noise can exist similar in an image as Gaussian noise. Its probability density function follows gamma distribution, which is shown in Fig

3. RESTORATION IN THE PRESENCE OF NOISE ONLY- SPATIAL FILTERING

Filtering to Remove Noise

We can use spatial filters of different kinds
to remove different kinds of noise

ARITHMETIC MEAN FILTER

The arithmetic mean filter is a very simple one and is calculated as follows:

$$f(x,y) = \frac{1}{mn}\sum g(s,t)$$

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

OTHER MEANS

There are different kinds of mean filters all of which exhibit slightly different behaviour:

– Geometric Mean
– Harmonic Mean
– Contraharmonic Mean

3.1 GEOMETRIC MEAN

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

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

3.2 HARMONIC MEAN

$$f(x,y) = \frac{mn}{\sum \frac{1}{g(x,y)}}$$

Works well for salt noise, but fails for pepper noise Also does well for other kinds of noise such as Gaussian noise

3.3 CONTRAHARMONIC MEAN

$$f(x,y) = \frac{\sum g(s,t)^{Q+1}}{\sum g(s,t)^{Q}}$$

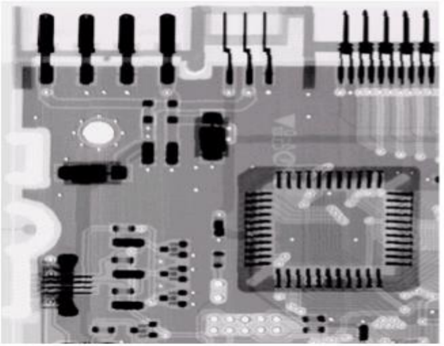
Q is the order of the filter and adjusting its value changes the filter's behavior :

Positive values of Q eliminate pepper noise

Negative values of Q eliminate salt noise

NOISE REMOVAL EXAMPLES

Original Image



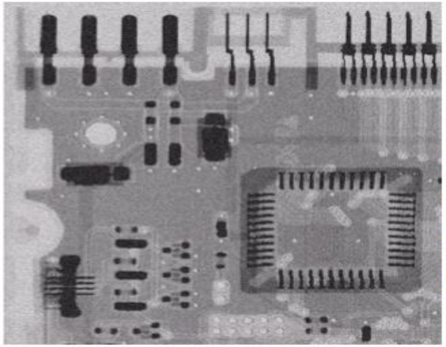
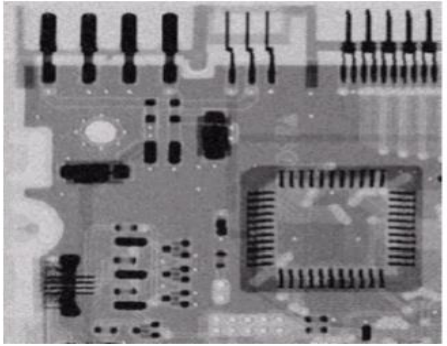
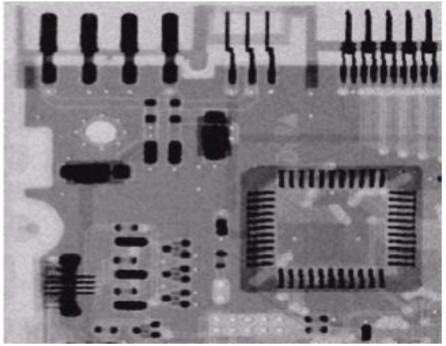


Image Corrupted By Gaussian Noise

After A 3*3 Arithmetic Mean Filter

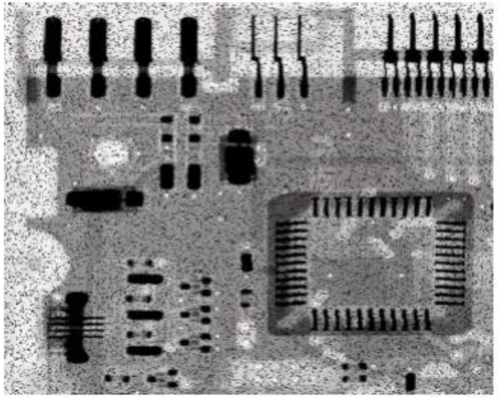




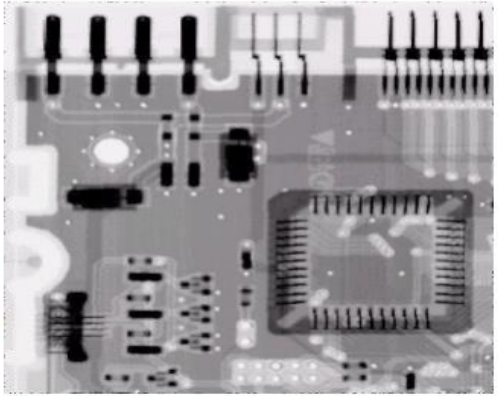
After A 3*3 Geometric Mean Filter

NOISE REMOVAL EXAMPLES

Image Corrupted By Pepper Noise



Result of Filtering Above With 3*3 Contraharmonic Q=1.5



NOISE REMOVAL EXAMPLES

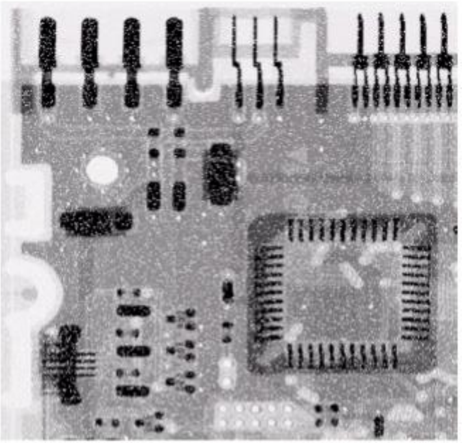
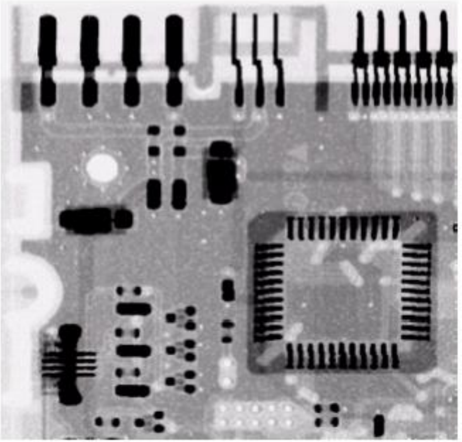


Image Corrupted By Salt Noise



Result of Filtering Above With 3*3 Contraharmonic Q=-1.5

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

– Max and min filter

– Midpoint filter

– Alpha trimmed mean filter

MEDIAN FILTER

$$f(x, y) = median\{g(s, t)\}$$

Excellent at noise removal, without the smoothing effects that can occur with other smoothing filters

Particularly good when salt and pepper noise is present

MAX AND MIN FILTER

Max Filter:

$$f(x, y) = Max\{g(s, t)\}$$

Min Filter:

$$f(x, y) = Min\{g(s, t)\}$$

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

MIDPOINT FILTER

$$f(x,y) = \frac{1}{2}[Max\{g(s,t)\} + Min\{g(s,t)\}]$$

Good for random Gaussian and uniform noise

NOISE REMOVAL EXAMPLES

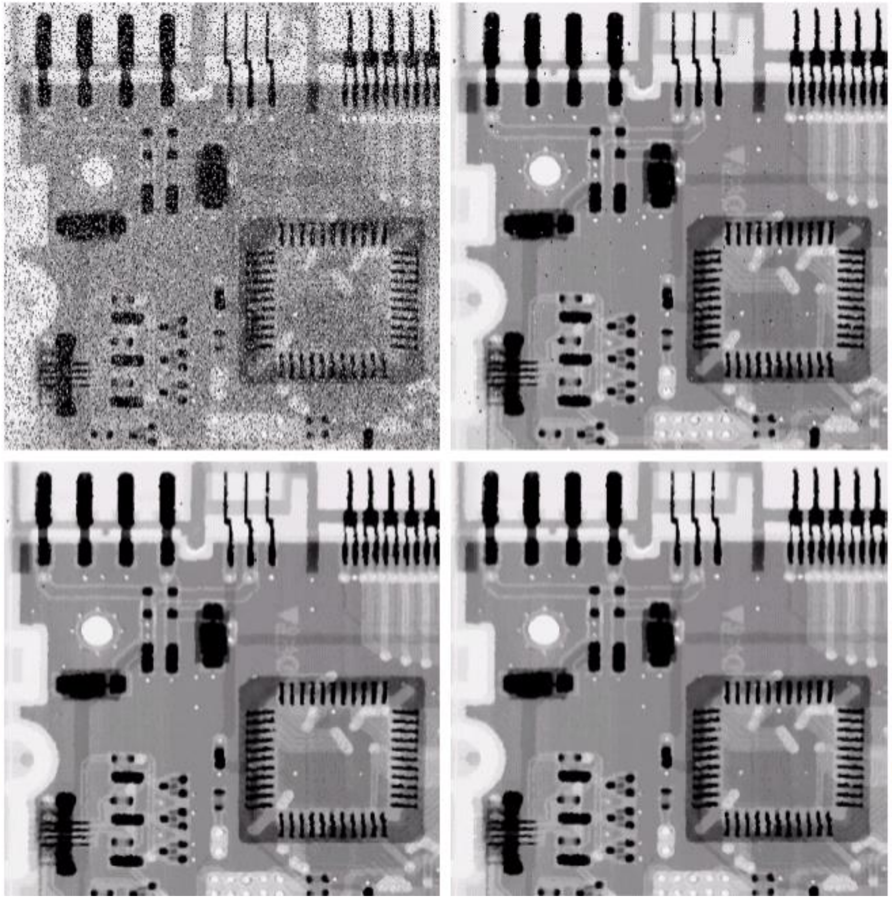


Image Corrupted By Salt And Pepper Noise

Result of 1 Pass With A 3*3 Median Filter

Result of 2 Passes With A 3*3 Median Filter

Result of 3 Passes With A 3*3 Median Filter

NOISE REMOVAL EXAMPLES

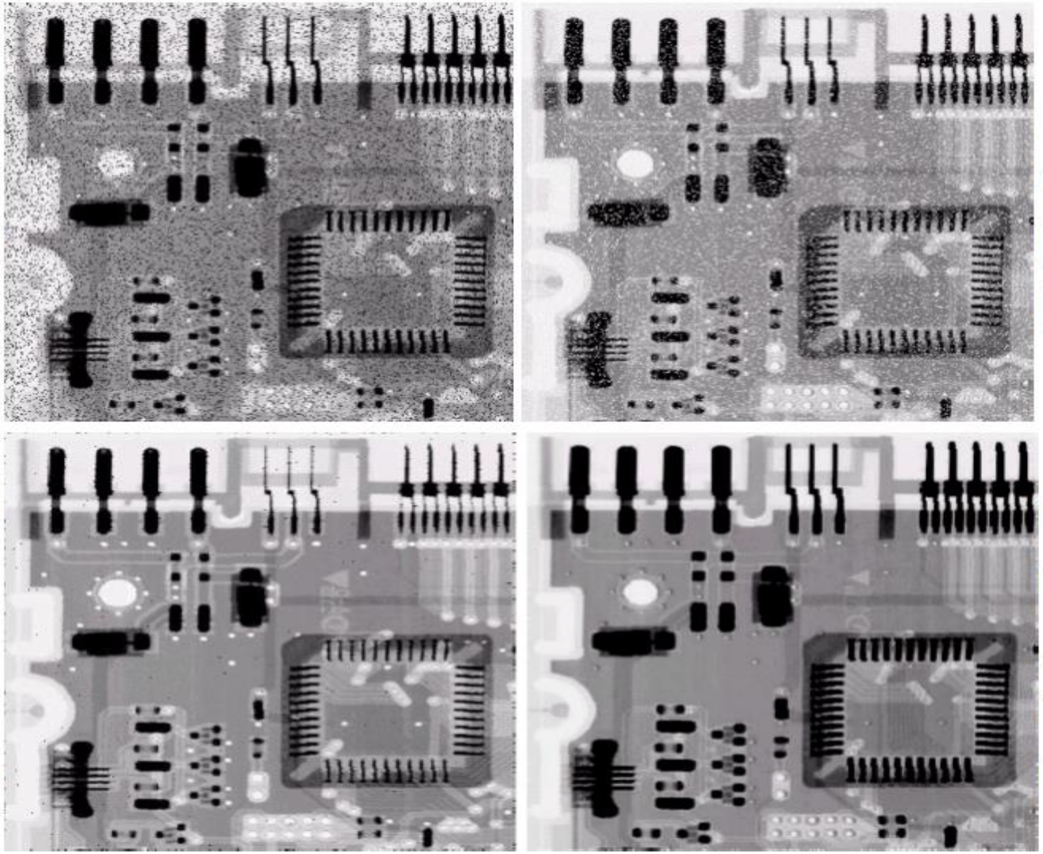


Image Corrupted By Pepper Noise

Image Corrupted By Salt Noise

Result Of Filtering Above With A 3*3 Max Filter

Result Of Filtering Above With A 3*3 Min Filter

ADAPTIVE FILTERS

the filters discussed so far are applied to an entire image without any regard for how image characteristics vary from one point to another The behaviour of adaptive filters changes depending on the characteristics of the image inside the filter region We will take a look at the adaptive median filter

The key insight in the adaptive median filter is that the filter size changes depending on the characteristics of the Image

the adaptive median filter has three purposes:

– Remove impulse noise
– Provide smoothing of other noise
– Reduce distortion

ADAPTIVE FILTERING EXAMPLE

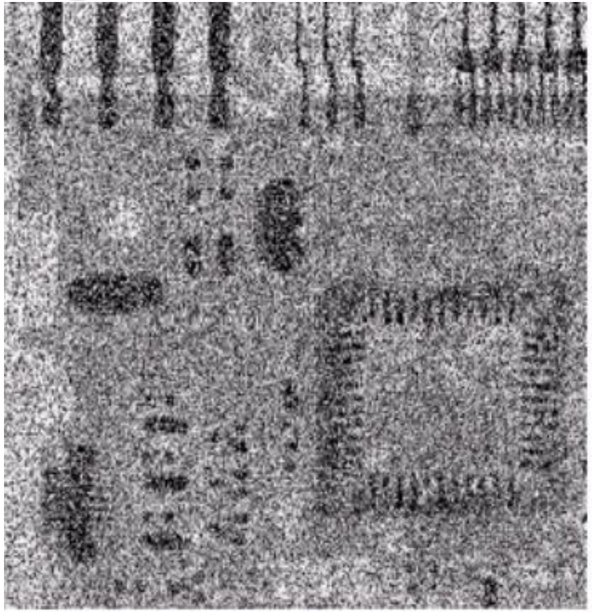
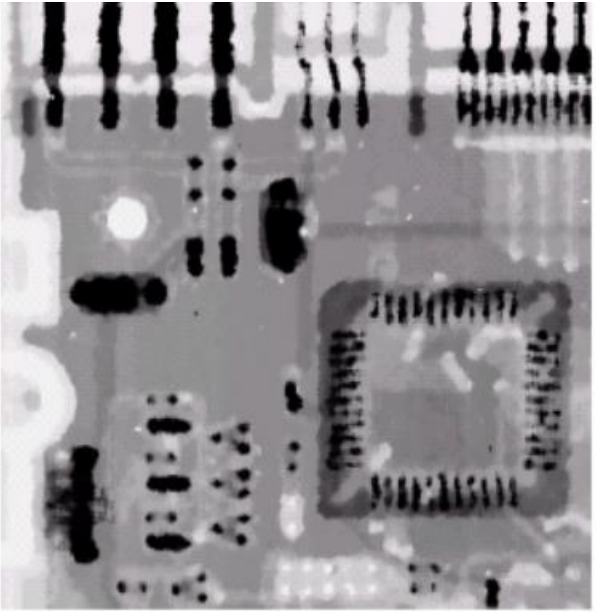
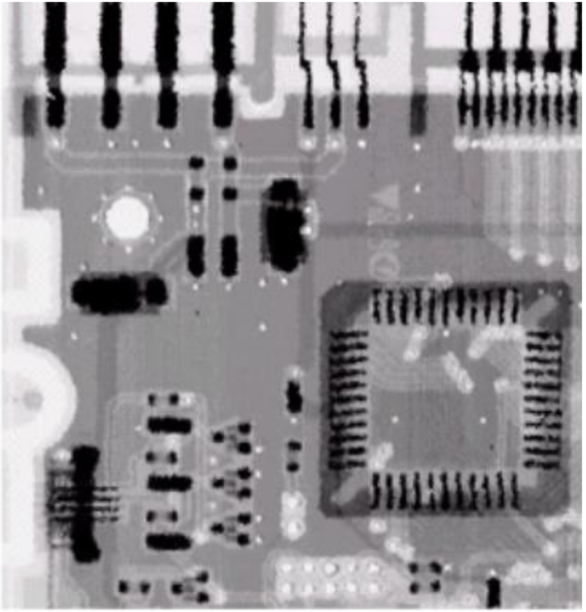


Image corrupted by salt and pepper noise with probabilities $P_a = P_b = 0.25$



Result of filtering with a 7 * 7 median filter



Result of adaptive median filtering with i = 7

4. PERIODIC NOISE REDUCTION USING FREQUENCY DOMAIN FILTERING

4.1 WHAT IS PERIODIC NOISE ?

Periodic noise is an unwanted signal that interferes with the source image or signal at a random frequency, depending on its source.

4.2 PERIODIC NOISE SOURCES

1. Nature

2. Electricity network

3. Electronics devices.

ORIGINAL IMAGE | PERIODIC NOISE

(a)

(b)

Figures: a) Source image. b) Corrupted image with periodic noise in spatial domain.

4.3 AMPLITUDE SPECTRUM

Unfortunately, an efficient spatial filter for periodic noise reduction in an image has not been developed yet. However, recovering the image tends to become easier in the frequency domain because of evident noise peaks as shown in Figure.

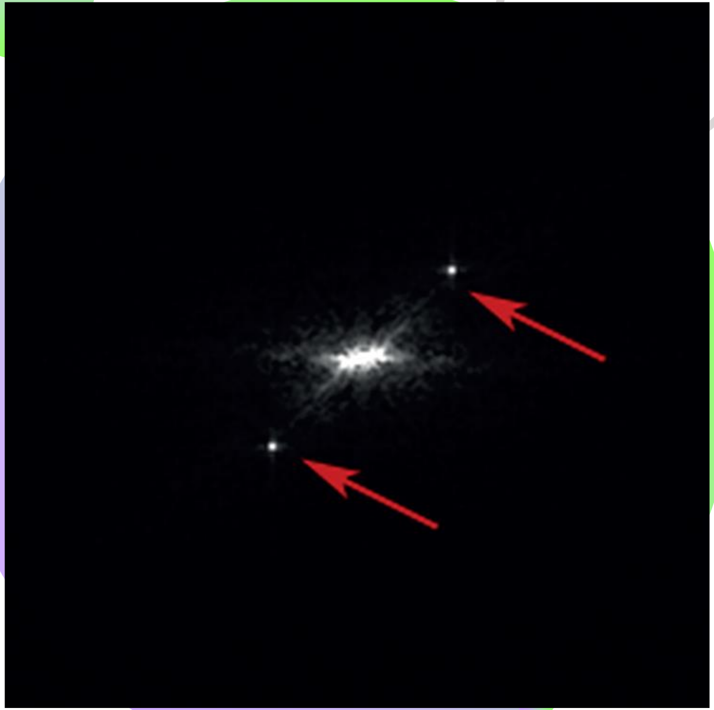


Fig. 2D demonstration of peak points in a noisy image's amplitude spectrum.

4.4 PERIODIC NOISE FILTERS

- In the last figure, we found that the noise is like peaks so it will be better to use the frequency domain to remove noise, so the frequency domain filters are used. The most used filters:

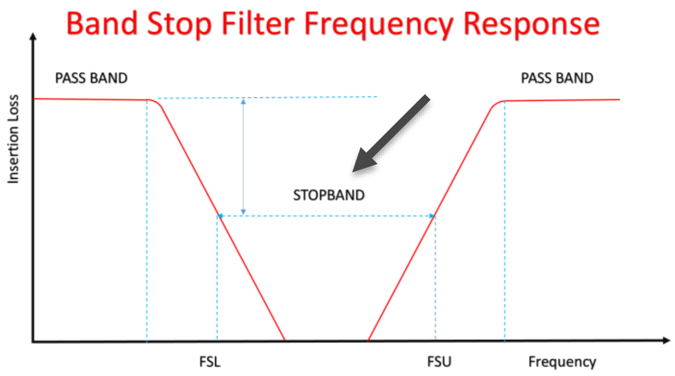
1. Band-reject Filters

2. Band-pass Filters

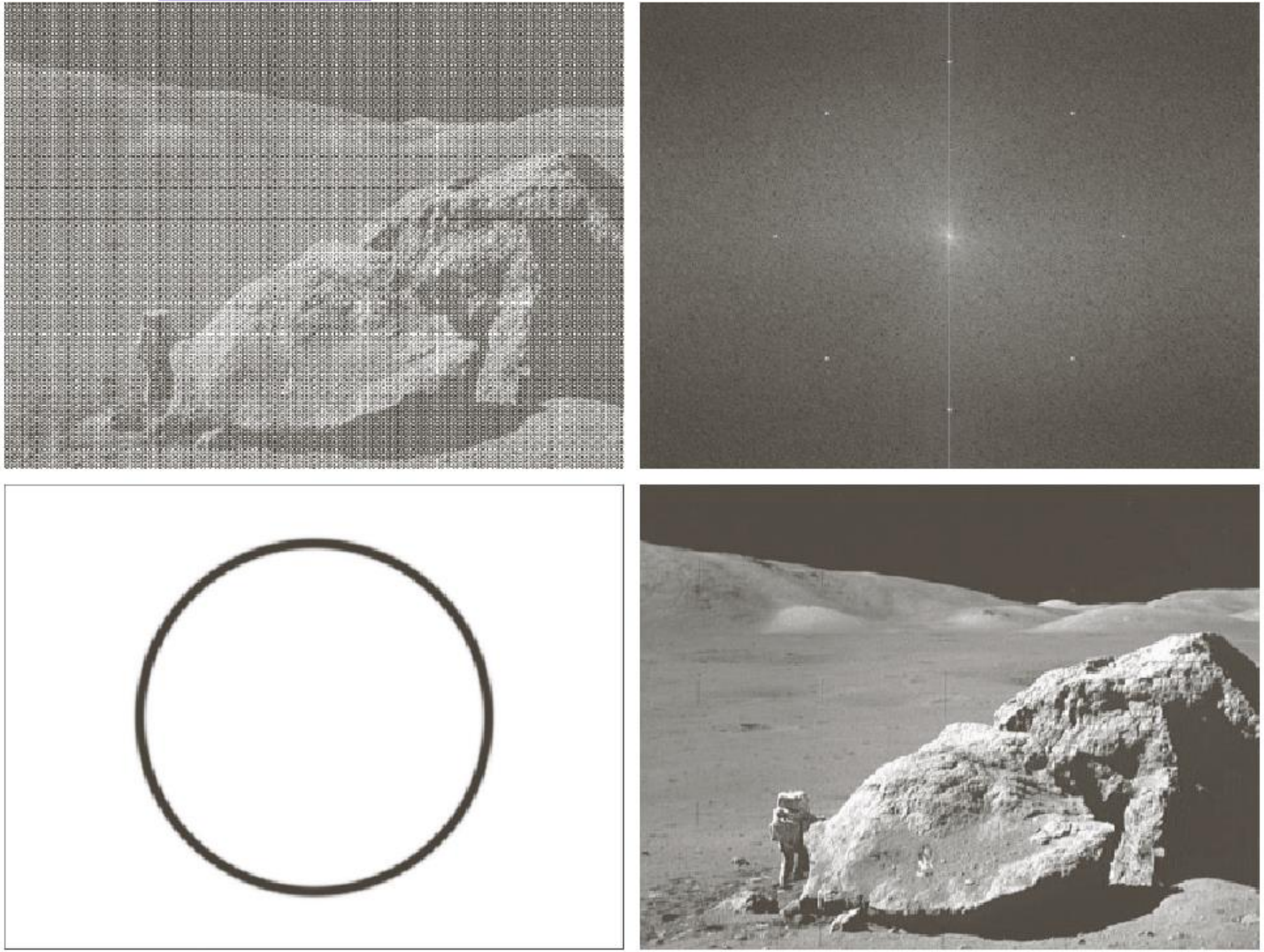
3. Notch Filters

4.4.1. BAND-REJECT FILTER

- A band reject filter is useful when the general location of the noise in the frequency domain is known. A band reject filter blocks frequencies within the chosen range and lets frequencies outside of the range pass through.



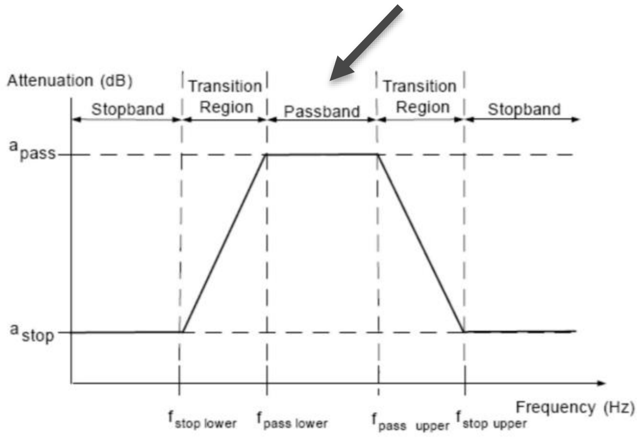
$$H(u,v) = \begin{cases} 1, & D(u,v) < D_o - \frac{w}{2} \\ 0, & D_o - \frac{w}{2} \leq D(u,v) \leq D_o + \frac{w}{2} \\ 1, & D(u,v) > D_o + \frac{w}{2} \end{cases}$$



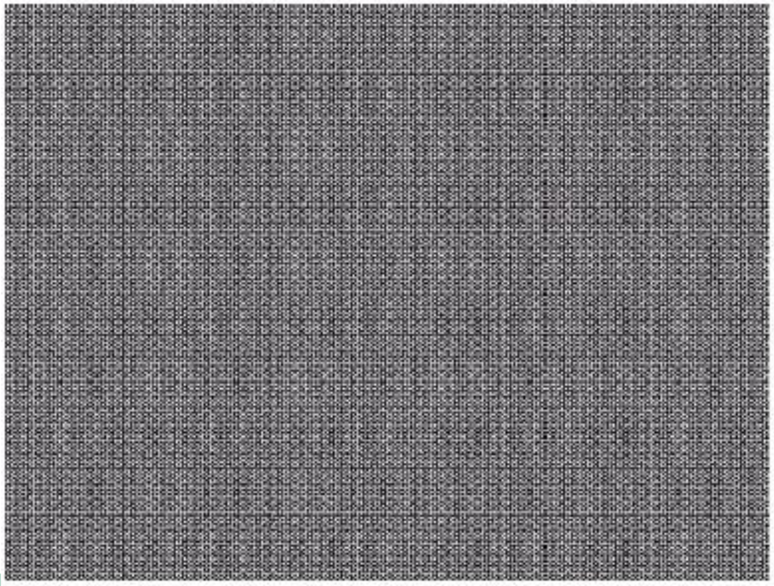
(a) Image corrupted by sinusoidal noise. (b) Spectrum of (a). (c) Butterworth bandreject filter (white represents 1). (d) Result of filtering.

4.4.2. BAND-PASS FILTER

- Bandpass filtering is usually used to isolate components of an image that correspond to a band of frequencies can also be used to isolate noise interference, so that more detailed analysis of the interference can be performed, independent of the image. A band pass filter passes frequencies within the chosen range and blocks frequencies outside the range.



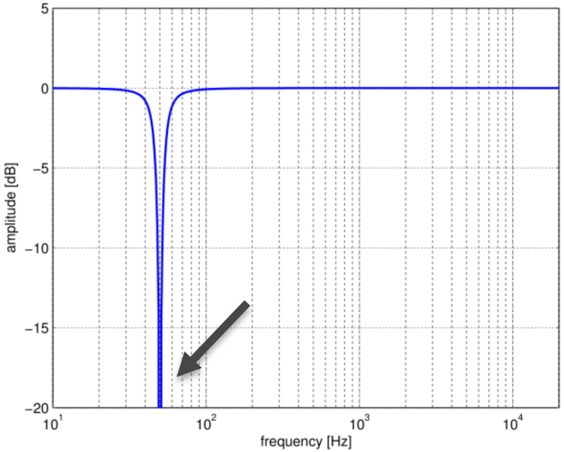
$$H_{BP}(u,v) = 1 - H_{BR}(u,v)$$



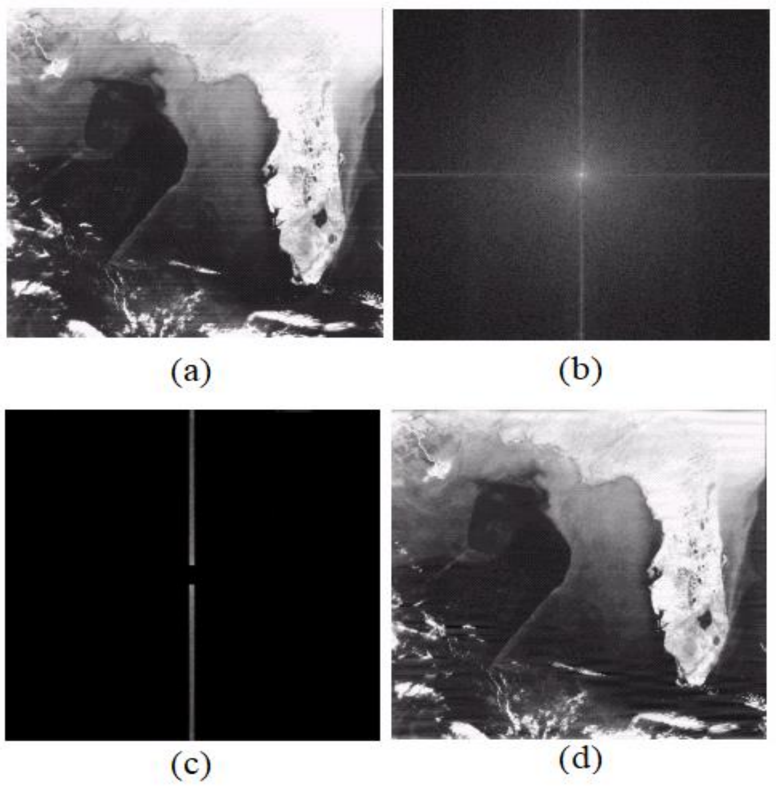
Noise pattern of the image in the last Figure obtained by bandpass filtering.

4.4.3. NOTCH FILTER

- Notch-filters help to eliminate noises from digital images. It is a kind of band-reject/band-pass filter that rejects/passes a very narrow set of frequencies, around a center frequency.



$$H_{NP}(u,v) = 1 - H_{NR}(u,v)$$



(a) Original image. (b) Spectrum of (a). (c) Notch pairs filter. (d) Result of notch reject.

THANKS

Do you have any questions?