

Chapter -4 Digital Smoothing Filter

(4-1) Filters: - There are several types of filters, including

- 1- Optical Filters 2- digital Filters 3- electronic Filters

(4-2) Digital Filters: - The filter needs time to be applied, which may be a second, an hour, or more.

➤ **Filters are used for**

- 1- Noise Removal Filters 2- Image Enhancement Filters

In digital image processing, smoothing operations are used to remove noise. Image filtering is the most important part of the smoothing process

Filtering techniques enhance and modify digital images. They also blur and reduce noise, sharpen, and detect edges. Image filters are mainly used to suppress high (smoothing techniques) and low frequencies (image enhancement, edge detection). The classification of image filters is as follows.

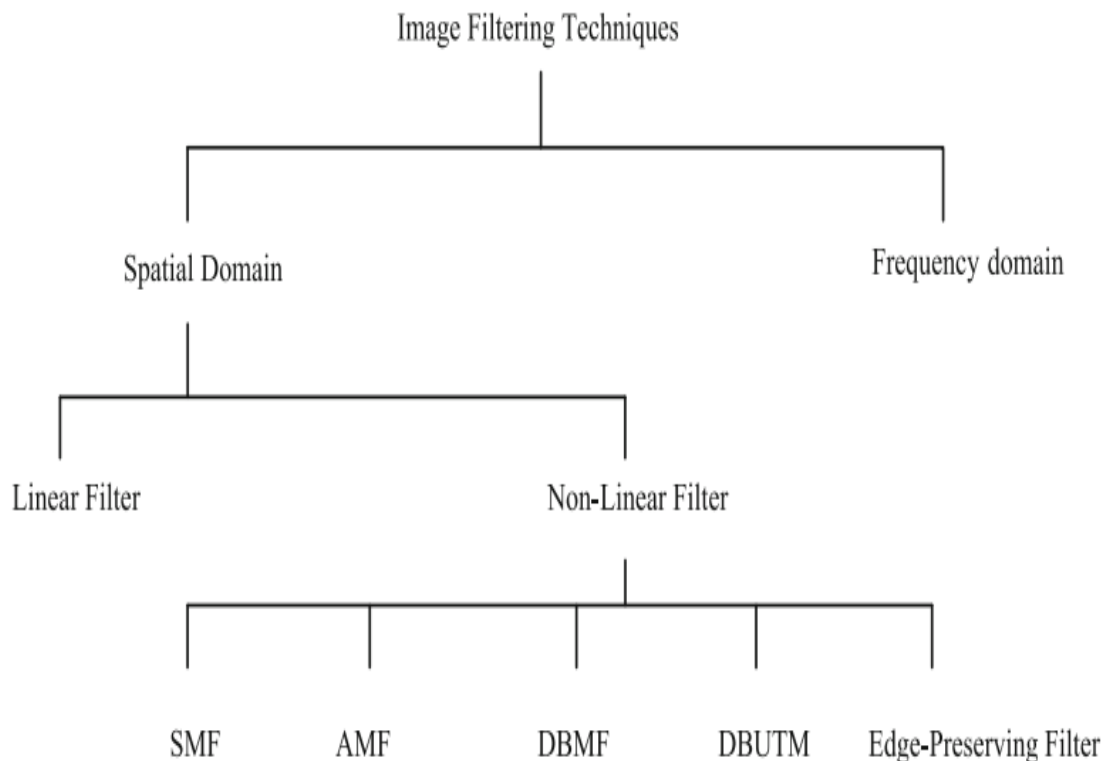


Fig (4-1) Classification of image filters (Simple Adaptive Median filter (AMF), Decision-Based Median Filter (DBMF), Decision-Based Untrimmed Median Filter (DBUTM))

According to this classification, image filters can be divided into two main categories. Spatial filtering is the traditional method of image filtering; it is used directly on the image pixels, while Frequency domain filters are used to remove high and low frequencies and smoothing.

Nonlinear filters are used to detect edges. Those filtering techniques are more effective than linear filters. In linear filtering, image details and edges are tended to blur. Gaussian filter, Laplacian filter, and Neighborhood Average (Mean) filter can be identified as examples of linear filters. Median filters are nonlinear filters.

(4-2-1) Spatial domain: -

The spatial domain refers to image operators that change the gray value at any pixel (x, y) depending on the pixel values in a square neighborhood centered at (x, y) using a fixed integer matrix of the same size. The integer matrix is called a filter, mask, kernel, or window.

The mechanism of spatial filtering shown in Fig (4-2), consists simply of moving the filter mask from pixel to pixel in an image. At each pixel (x, y) , the response of the filter at that pixel is calculated using a predefined relationship (linear or nonlinear)

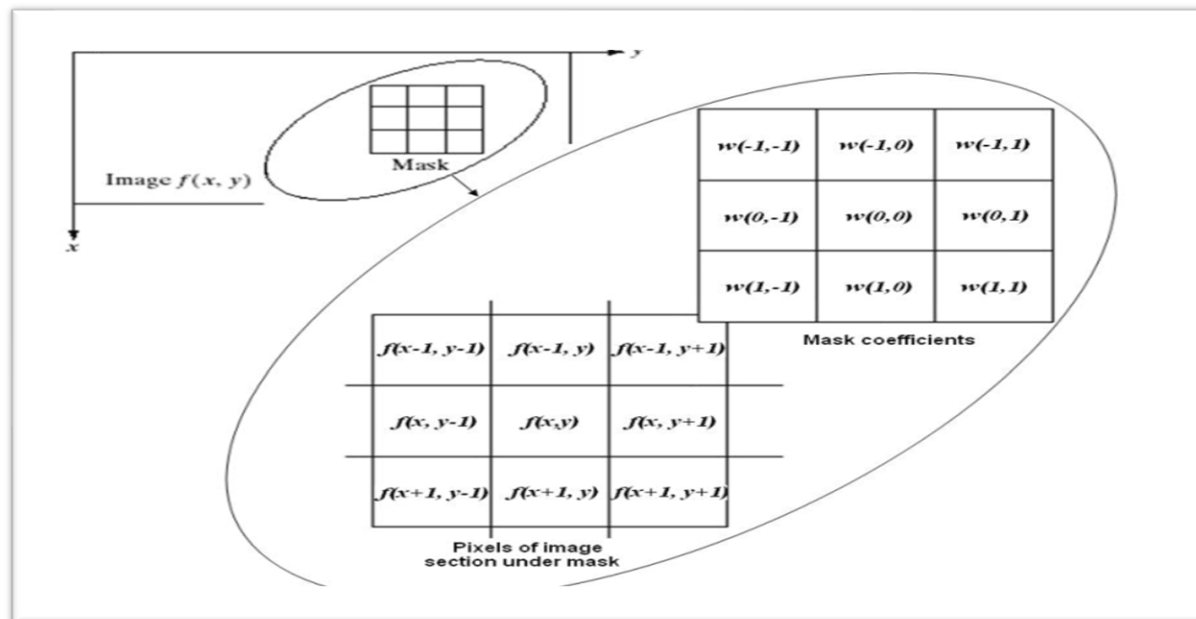


Fig. (4-2) The spatial filtering

(4-2-1-1) Traditional Filters

a-Neighborhood Average (mean, Box) Filters: -

This filter is also called a mean filter. In average filtering, pixel values will be replaced by the average values of neighboring pixels. The calculation of the average value is as follows.

23	25	30	35	30
25	30	35	37	40
45	40	37	43	45
38	40	43	42	46
35	40	42	45	47

		39		

$$\text{Value} = (30 + 35 + 37 + 40 + 37 + 43 + 40 + 43 + 42) / 9 = 38.55 = 39$$



Average Filter

$$I(x, y) = R(x, y) + n(x, y)$$

$$M(x, y) = \frac{1}{B \times B} \sum_{x=1}^B \sum_{y=1}^B I(x, y)$$

$$M(x, y) = \frac{1}{B^2} \sum_{i=x-B/2}^{x+B/2} \sum_{j=y-B/2}^{y+B/2} I(i, j)$$

معادلة تحريك الفلتر

- ❖ النوافذ قد تكون 3x3، 5x5، 7x7، 9x9، 11x11 يكون حجم الفلتر دائما فرديا وليس زوجيا؟
- ❖ لأنه لدينا حالة تناظر حول العنصر المركزي في حالة نافذة فردية وإذا كانت زوجية يحصل اضعاف للصورة الاصلية.

ملاحظة مهمة جدا: -

- إذا كان مجموع اوزان الفلتر = صفر الفلتر يستخدم للحافات (Edge)
- إذا كان مجموع اوزان الفلتر = 1 الفلتر يستخدم للتجانس (Smoothing)
- إذا كان مجموع اوزان الفلتر لا يساوي صفر او 1 الفلتر يستخدم لحدة الصورة (Sharpening).

b-Median Filter

The median filter is non-linear. Typically, these filters operate on a small sub-image, “Window”, and replace the center pixel value (similar to the convolution process). It is considered the best filter because it **is non-linear and** simply calculates statistics. The median filter is used to preserve edge properties while reducing the noise in the image, and also, it's an efficient way to remove salt-and-pepper noise.

Order statistics is a technique that arranges the entire pixels in sequential order, given an $N \times N$ window (W), the pixel values can be ordered from the smallest to the largest (ascending order). $I_1 < I_2 < I_3 < \dots < I_N$ ²

■ Where $I_1, I_2, I_3, \dots, I_N$ are the intensity values of pixels within the ($N \times N$) window



a. Salt and pepper noise



b. Median filtered image (3x3)

The calculation of the median value is given below.

30	35	40	42	42
35	42	37	37	40
38	39	40	41	42
40	41	42	43	43
42	43	45	44	46

		41		

37, 37, 39, 40, **41**, 42, 42, 43



C- Mode: The most frequent value. In any given data set, there may be one mode or more than one mode, or there may be no mode, and it is used for segmentation. The Mode filter is used to remove noise from an image by replacing pixels with the most frequently occurring pixel value selected from a certain window size.

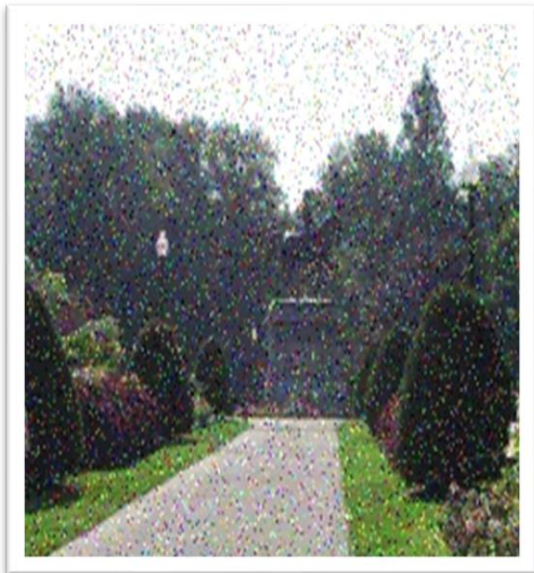
For example, given the grayscale 3x3 pixel window;

22	77	48
150	77	154
0	77	219

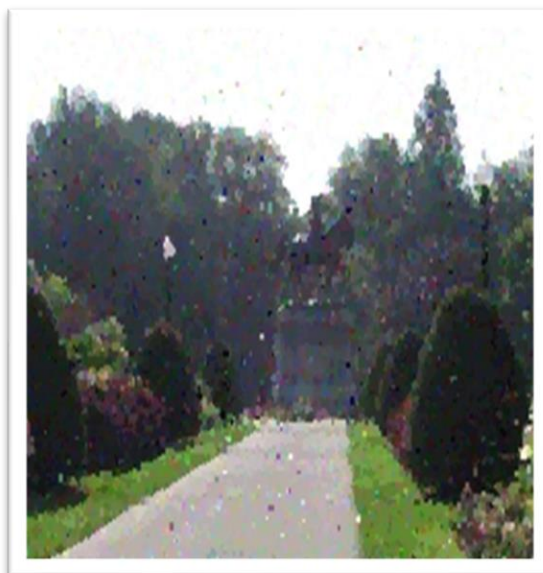
Thus, the center pixel would be at 77 since 77 is the most frequently occurring value in the list of pixels.

The mode filter (like the median filter) is very effective at removing noise while not destroying sharp edges in an image.

Origin image with Noise



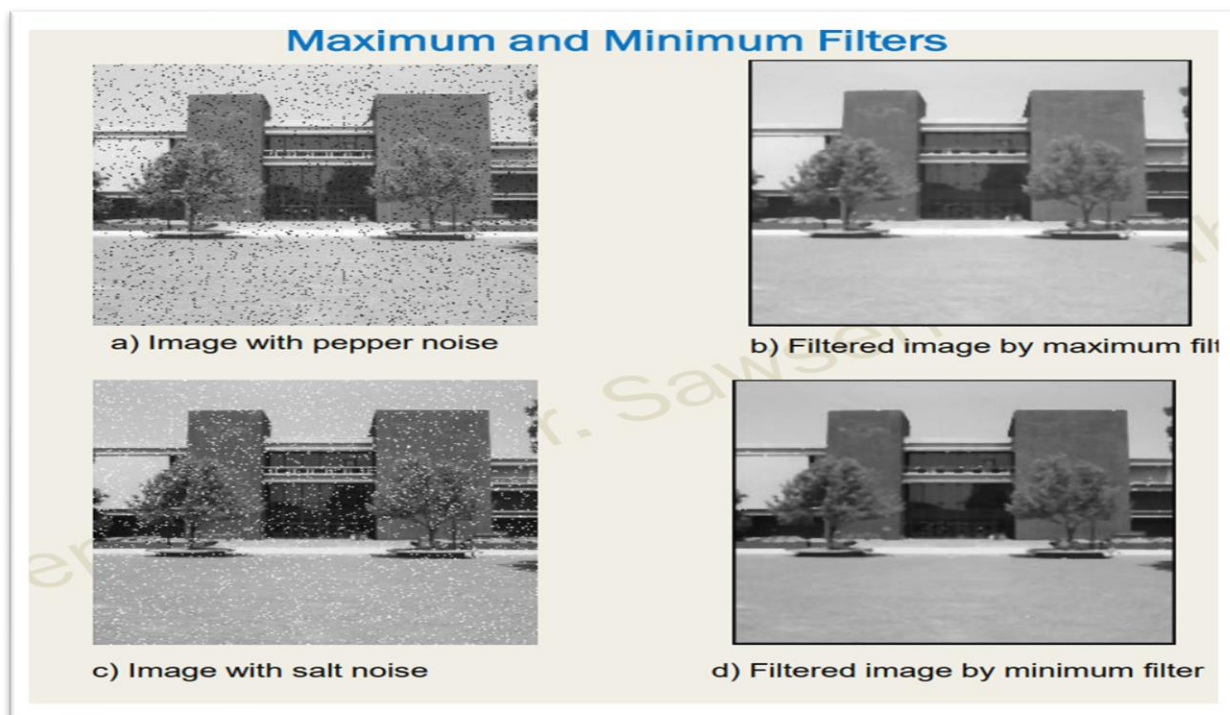
Mode Filter



D- Min & Max: -

Maximum and Minimum Filters are two-order filters that can be used for the elimination of salt-and-pepper noise.

- The maximum filter selects the largest value within an ordered window of pixel values and replaces the central pixel with the largest value (lightest one).
- Used to find the brightest points in an image.
- The maximum filters work best for removing pepper-type noise.
- The minimum filter selects the smallest value within an ordered window of pixel values and replaces the central pixel with the smallest value (darkest one) in the ordered window.
- The minimum filters work best for removing salt-type noise, NOTE:- a minimum or low-rank filter will tend to darken an image, and a maximum or high-rank filter will tend to brighten an image.



Example: - If Image

4	5	7	15	20
8	7	8	11	20
4	5	2	17	21
15	25	30	32	10

Apply Traditional filters on 17 No.

1-Mean filter. 2- Median filter. 3-Mode.

4- (Min, Max) filter.

Solution: -

$$1\text{-Mean Filter} = 1/9 (8+11+20+2+17+21+30+32+10)$$

$$= 16.7 = \text{Cint} (16.7) = \mathbf{17 \text{ the mean}}$$

$$2\text{-Median} = 2, 8, 10, 11, \mathbf{17}, 20, 21, 30, 32$$

3-Mode  Don't find the element

4-Min = 2 يعمل الصورة اكثر سوادا لأنه

Salt يتخلص من النقاط البيضاء في الصورة

5- Max = 32

يعمل الصورة اكثر بياضا لأنه

(Pepper) يتخلص من النقاط السوداء

H.W: - Apply Traditional filters on (8, 5) No.

1-Mean filter. 2- Median filter. 3-Mode.

4- (Min, Max) filter: -

4	5	8	15
8	7	8	11
4	5	2	17
15	25	30	32

E- Laplacian Filter...

The Laplace smoothing technique is mainly used to detect image edges. It highlights gray-level discontinuities. It is based on the second spatial derivation of an image. The equation below has been used to define the Laplacian operator.

$$\text{Laplace}(f) = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

Laplace edge detectors use only one kernel. To detect the edges of an image, this kernel detects 2nd-order derivatives of the image's intensity levels by using only a single pass. We can use "kernel 2" to detect edges with diagonals. It will give a better approximation. Also, the Laplace method gives faster calculations than others.

0	-1	0
-1	4	-1
0	-1	0

Kernel 1

-1	-1	-1
-1	8	-1
-1	-1	-1

Kernel 2



Kernel 1



Kernel 2

F- Gaussian Filter

This filter is a 2-D convolutional operator. It is used to blur images. Also, it removes details and noises. The Gaussian filter is similar to the mean filter. But the main difference is, that the Gaussian filter uses a kernel. That kernel has a shape of a Gaussian hump. Gaussian kernel weights pixels at its center much more strongly than its boundaries. There are different Gaussian kernels. Based on the kernel size, the output image will be different.

$$\frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \quad \frac{1}{273} \times \begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}$$



3X3 Kernel



5x5 Kernel