Digital Image Processing
Notes

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1 Gaussian Smoothing Filter

- It is nothing but weighted averaging.
- Gives more weight at the central pixels and less weights to the neighbors.
- The farther away the neighbors, the smaller the weight
- There will be no ringing artifacts due to the apply of this filter because fourier transform of gaussian curve is also a gaussian and it doesnot have zero crossings.

$$G(x,y) = e^{-(x^2+y^2)/(2\sigma^2)} \tag{1}$$

Figure 1: Original image

Figure 2: Image after applying Gaussian smoothing filter with neighbourhood matrix 7 x 7, variance 3

Figure 3: Image after applying box filter 11 x 11

2 Median Filter

- This filter replaces the Intensity value of the pixel by the median of values present in it's neighbourhood
- It is useful for removing isolated lines or pixels i.e helpful in removing impulse noise / salt and pepper noise.
- General window sizes are 5 x 5, 7 x 7

Figure 4: Original image with impulse noise

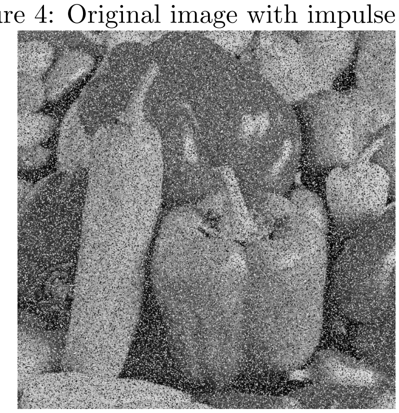
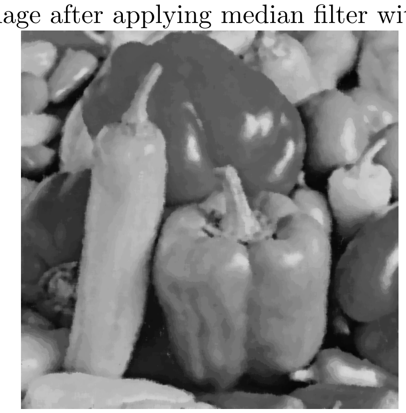


Figure 5: Image after applying median filter with mask 7 x 7



3 Noise Models

Two main Noise Models are Additive gaussian noise, Impulse Noise.

3.1 Additive Gaussian Noise

The noise model is additive in nature and follows Gaussian Distribution. It means that each pixel in a noisy image will have intensity equal to sum of actual pixel Intensity value and random noise which follows gaussian distribution.

This kind of noise can be introduced by channel while transmitting data of image through channel.

3.2 Impulse Noise (Salt and Pepper Noise)

Black and White dots appears in the image because of this noise.

This kind of noise can be introduced by analog to digital converters, bit errors during transmission etc.

This noise can be overcomed by using median filters.

4 Other Filtering Techniques

4.1 Unsharp masking and High-Boost filtering

These techniques helps to sharpen images (means highlighting the edges and fine details in an image).

4.1.1 Unsharp masking

- It involves subtracting a blurred version (smoothed) version of an image from the image itself
- It produces an edge image
- Now, the edge image can be added to original image to get sharpened image

$$f_s(x, y) = f_{original}(x, y) - f_{smooth}(x, y) \tag{2}$$

$f_k(x, y)$ is an image of type k.

4.1.2 High-Boost filtering

- This is a generalization of unsharp masking

  $f_{hb}(x, y) = Af_{original}(x, y) - f_{smooth}(x, y),$

  $f_k(x, y)$ is an image of type k, $A >= 1$

5 Gradient

We had seen that to blur an image we had replaced the pixel value by weighted mean or mean of it's neighbourhood pixel values. Averaging is analogous to integration. So, we can logically say that to sharpen (highlight fine details) an image we need to do differentiation.
In digital domain we calculate differentiation with the help of difference operator.

First order derivatives of a digital image are based on approximations of the 2-D gradient.

$$\Delta f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \\ \frac{\partial f}{\partial y} \end{bmatrix}$$
$$|\Delta f| = \sqrt{G_x^2 + G_y^2}$$

The above quantity gives the maximum rate of increase of $f(x, y)$ per unit distance in the direction of Δf. The direction of gradient vector is given by $\tan^{-1}(G_y/G_x)$.
Basic definition of first derivative of one dimentional function $f(x)$ is

$$\frac{\partial f}{\partial x} = f(x+1) - f(x)$$

In order to find gradient of an image we need to find partial derivatives along x and y at every pixel.

Let us consider a 3 x 3 neighbourhood of a pixel and let it be

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

We get $G_x = (z_7 + z_8 + z_9)$ - $(z_1 + z_2 + z_3)$

We get $G_y = (z_3 + z_6 + z_9)$ - $(z_1 + z_4 + z_7)$

The above equations are obtained when we use the following 3 x 3 masks respectively.

Table 1: Prewitt operator

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	0	1

Which means difference of first row and last row approximates the change in x direction and difference between first column and last column approximates the change in y direction.

We can use other operators like sober operators to help us in calculating gradient.
Sobel operators give more weight to the centre point of non-zero row or column.

Table 2: Sobel operator

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

Figure 6: Original image

Figure 7: Magnitude of G_y using sobel mask

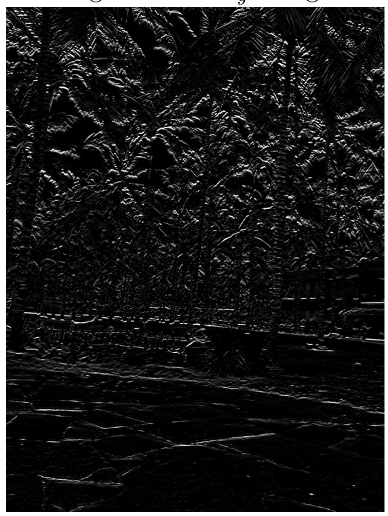


Figure 8: Magnitude of G_x using sobel mask

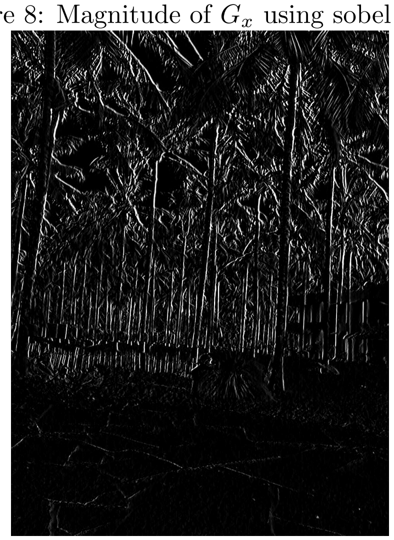


Figure 9: Gradient Image $|G_x| + |G_y|$

6 Edge Mapping

- We can achieve Edge mapping by using threshold over gradient image.
- By smoothing the image and then obtaining the gradient image of the smoothened image and thresholding, we get image with the principal edges highlighted.
- Thresholding is not always a good idea for edge mapping.

The following figures expain Edge Mapping by thresholding.

Figure 10: Original Image

Figure 11: Blurr image obtained using average filter of mask 5 x 5

Figure 12: Gradient image obtained from blur image

Figure 13: Image after thresholding by 33% of max value of gradient gradient image of blurred image