Report for Digital Image Processing

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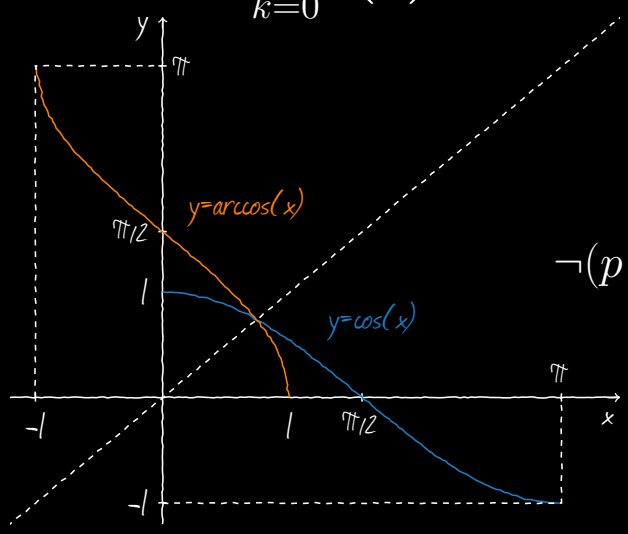
version 1.1

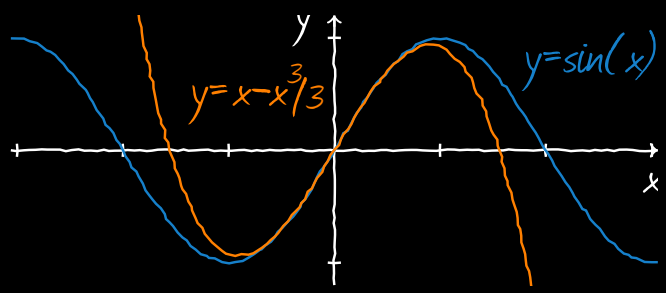
$$(a+b)^n = \sum_{k=0}^{n} \binom{n}{k} a^k b^{n-k}$$



$$\zeta_k = |a|^{1/n} \mathrm{e}^{i(\arg(a)+2k\pi)/n}$$

$$\mathrm{e}^{i\pi} + 1 = 0$$

$$\neg(p \vee q) \equiv (\neg p) \wedge (\neg q)$$



$$\binom{n}{k} = \frac{n!}{k!(n-k)!}$$

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1.1 OverView

(a) Write a computer program for computing the histogram of an image.
(b) Implement the histogram equalization technique.
(c) Your program must be general to allow any gray-level image as its input.
As a minimum, your report should include the original image, a plot of its histogram, a plot of the transformation function, the enhanced image, and a plot of its histogram.

1.2 Generate the Histogram

1.2.1 Function

Generating the histogram of an image using following function:

$$H(i) = the\ number\ of\ pixel\ whose\ value\ euquals\ to\ i \tag{1.1}$$

1.2.2 Histogram

The histogram pictures of Fig1.jpg and Fig2.jpg are listed as follows:

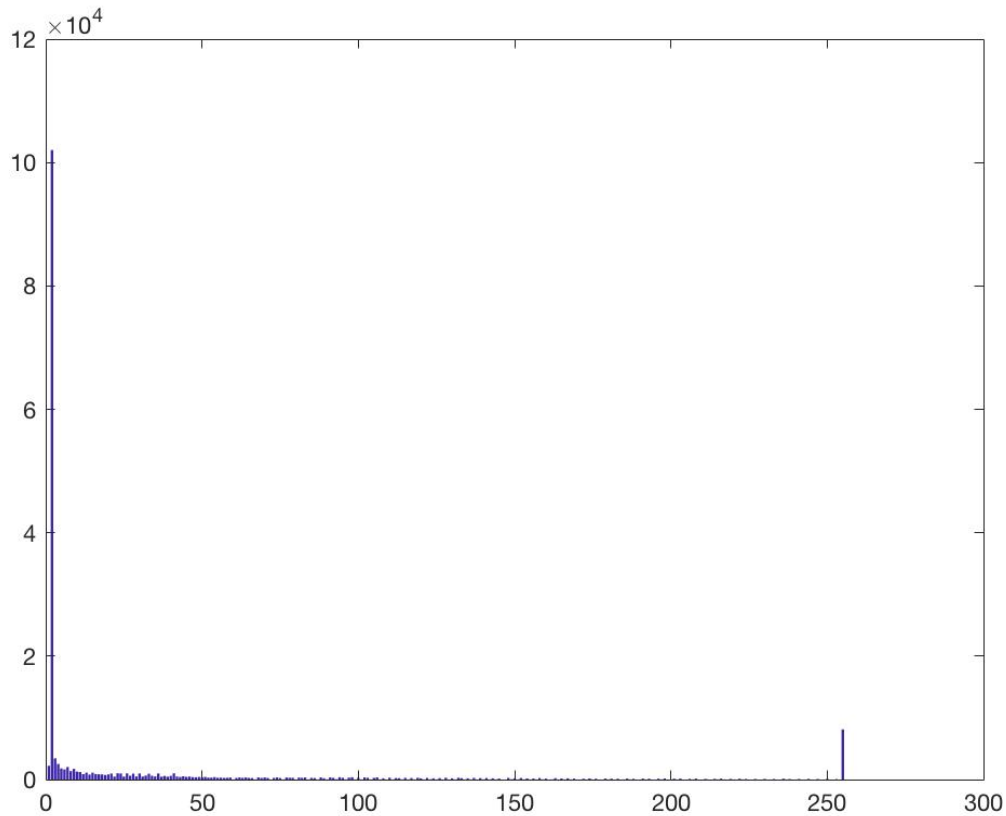

Figure 1.1: Histogram of fig1.jpg

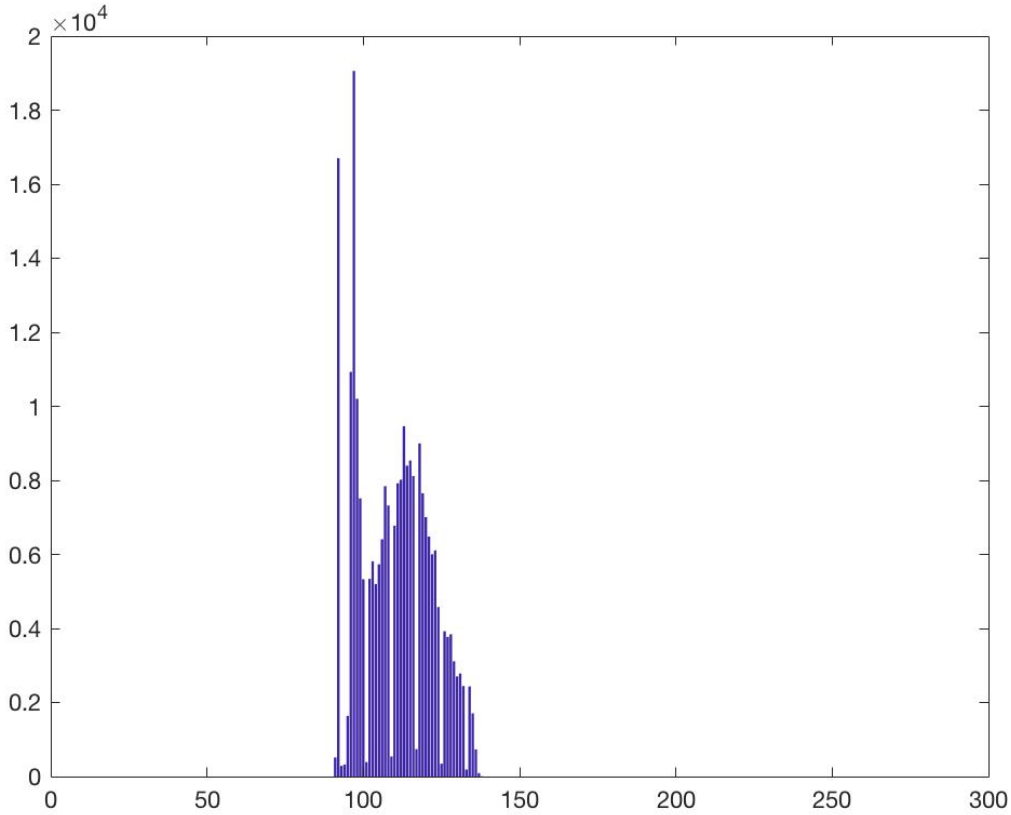

Figure 1.2: Histogram of fig2.jpg

1.3 Transfer Function

1.3.1 Implement the Histogram Equalization Technique

We use those functions to calculate the histogram equalization:

$$L = Max(image(r,c))\ \forall r \in [1, rows]\ and\ \forall c \in [1, cols] \tag{1.2}$$

$$s(r_k) = L * T(r_k) = L * \sum_{j=0}^{k} P_r(r_j) = L * \sum_{j=0}^{k} \frac{n_j}{n} \tag{1.3}$$

1.3.2 Transfer Function

The transfer function of Fig1.jpg and Fig2.jpg are listed as follows:

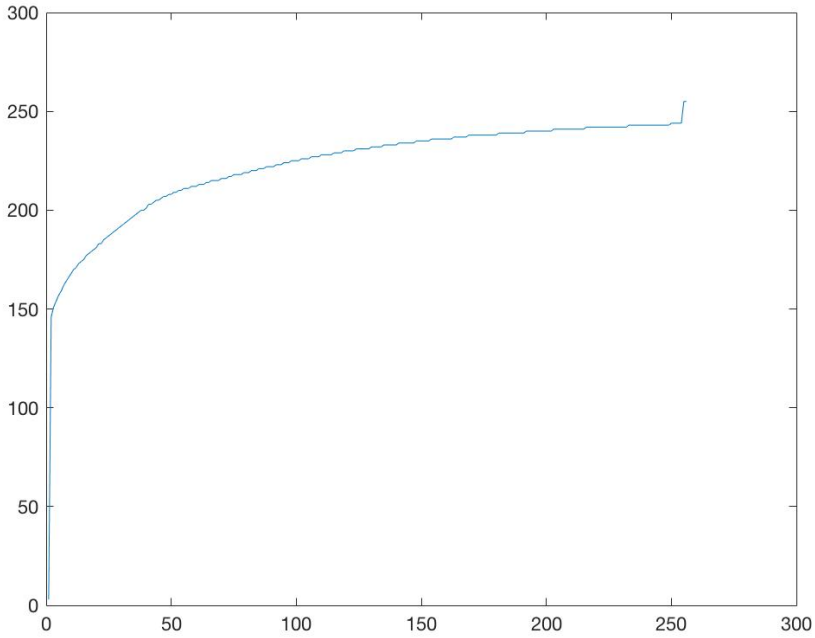

Figure 1.3: Transfer Function of fig1.jpg

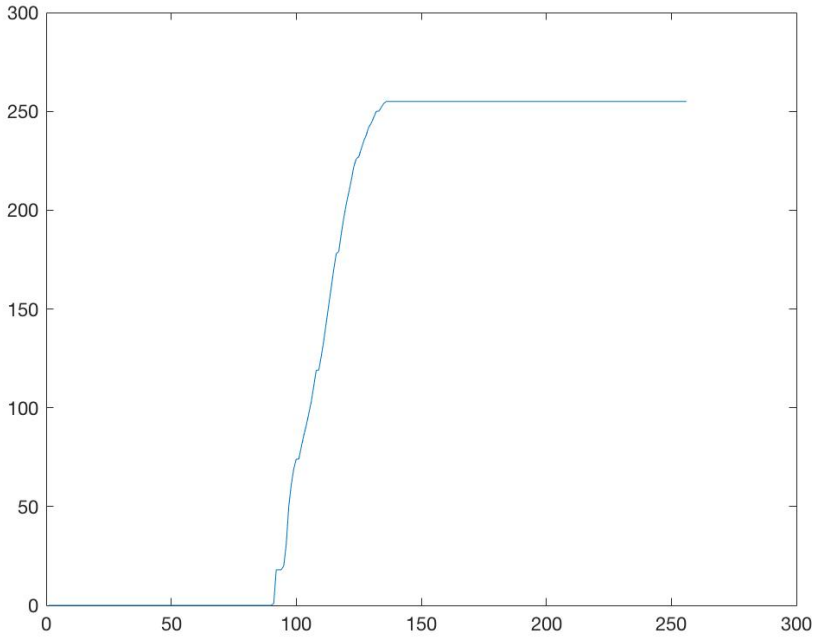

Figure 1.4: Transfer Function of fig2.jpg

1.4 Enhanced Images

1.4.1 Enhanced Function

We use the function

$$New\ Image(r,c) = Transfer\ Function(image(r,c))\ \forall r \in [1, rows]\ and\ \forall c \in [1, cols] \quad (1.4)$$

to enhance the original images.

1.4.2 Enhanced Images

The original images and enhanced images and histogram comparation are listed as follows.

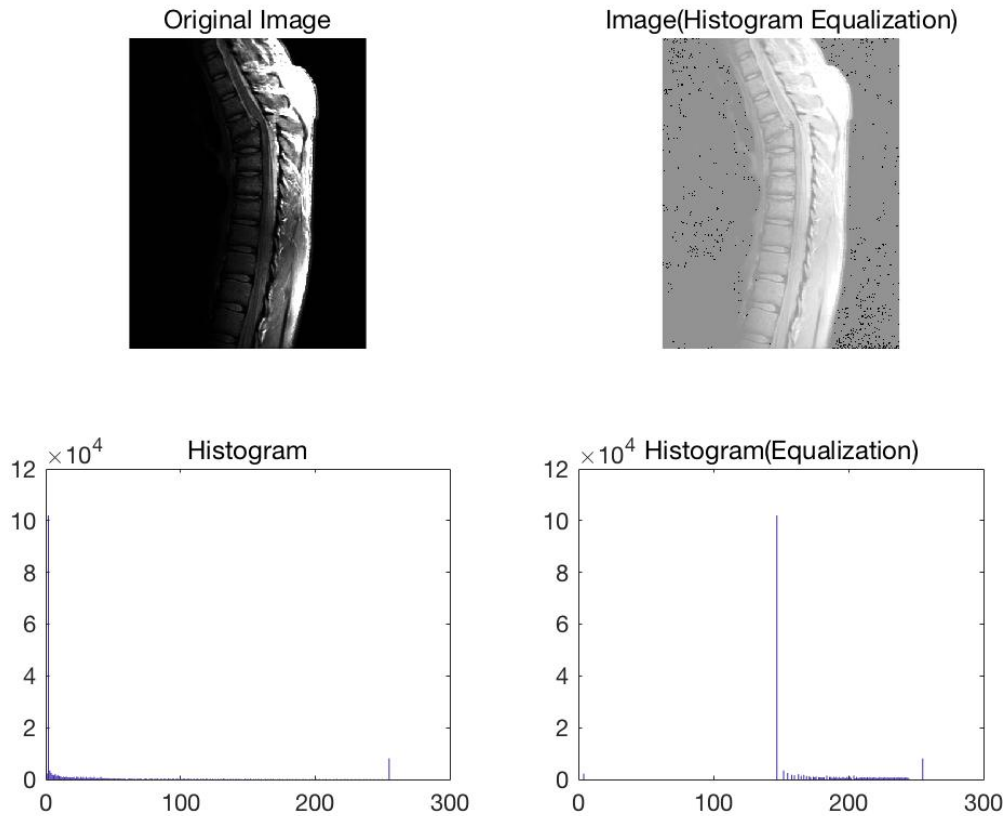

Figure 1.5: original image and enhanced image and histogram comparation of fig1.jpg

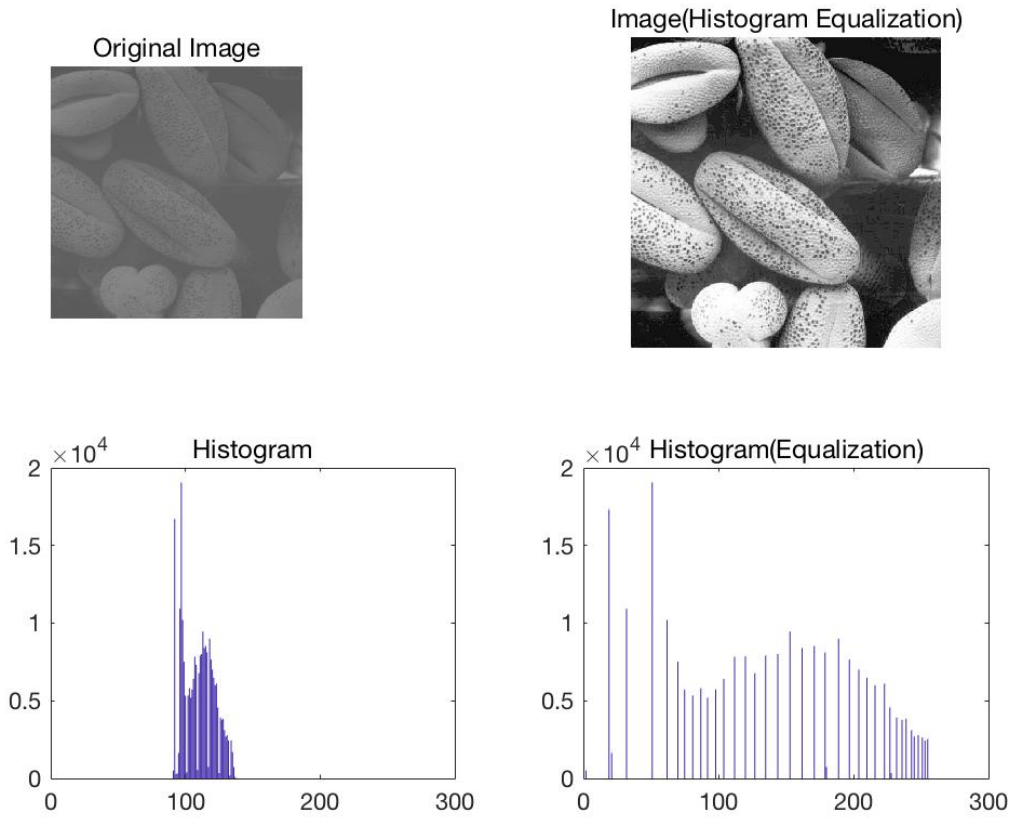

Figure 1.6: original image and enhanced image and histogram comparation of fig2.jpg

2.1 OverView

Implement the image enhancement task of Section 3.7 (Fig 3.43, page 171). The image to be enhanced is skeleton_orig.tif. You should implement all steps in Figure 3.43. (You are encouraged to implement all functions by yourself, not to directly use Matlab functions such as imfilter or fspecial.)

2.2 Image b

2.2.1 Laplacian Transform Filter

We apply Laplacian Transform on the original image to get the image (b) using the following filter.

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

2.2.2 Laplacian Transform

Image b:

Figure 2.1: Laplacian Transform of skeleton_orig.tif

2.3 Image c

The we add the Laplacian of the original image to the original image, we will get the new image c. The new image c is a rather noisy sharpened image.
Image c:

Figure 2.2: Laplacian Transform of skeleton_orig.tif

2.4 Image d

2.4.1 Sobel Gradient Masks

We will use two mask to separately get the components g_x and g_y. Then add the two components together, we will get the the sober gradient of the original image. The new image is as follows. As we can see, edges are much more dominant in this image than in the Laplacian image.

g_x:

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

g_y:

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

2.4.2 Image d

Image d:

Figure 2.3: Laplacian Transform of skeleton_orig.tif

2.5 Image e

Image e is formed by smoothing image d by 5*5 mean filter.
Image e:

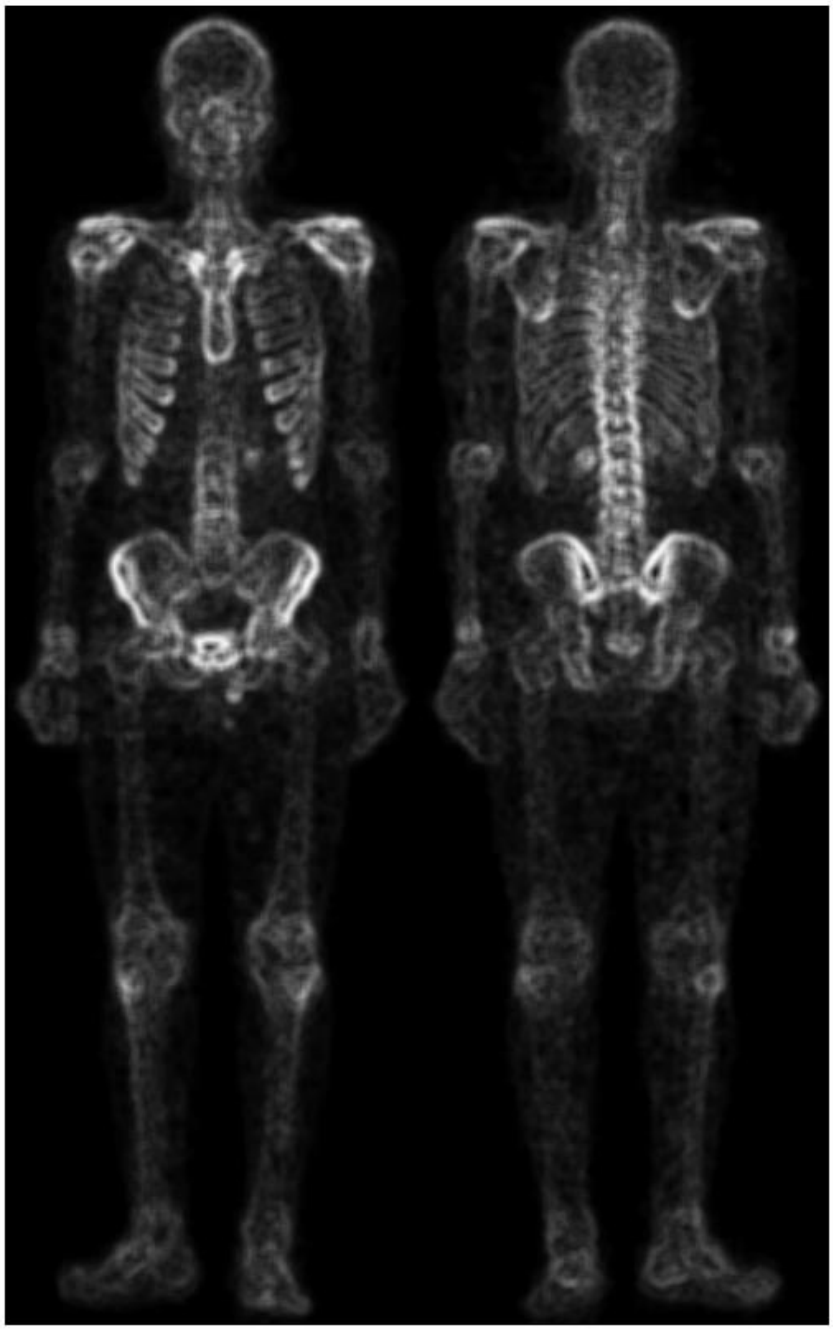

Figure 2.4: Laplacian Transform of skeleton_orig.tif

2.6 Image f

Image f is formed by the product of Laplacian and smoothed-gradient image. The dominance of the strong edges and the relative lack of visible noise, which is the key objective behind masking the Laplacian with a smoothed gradient image.
Image f:

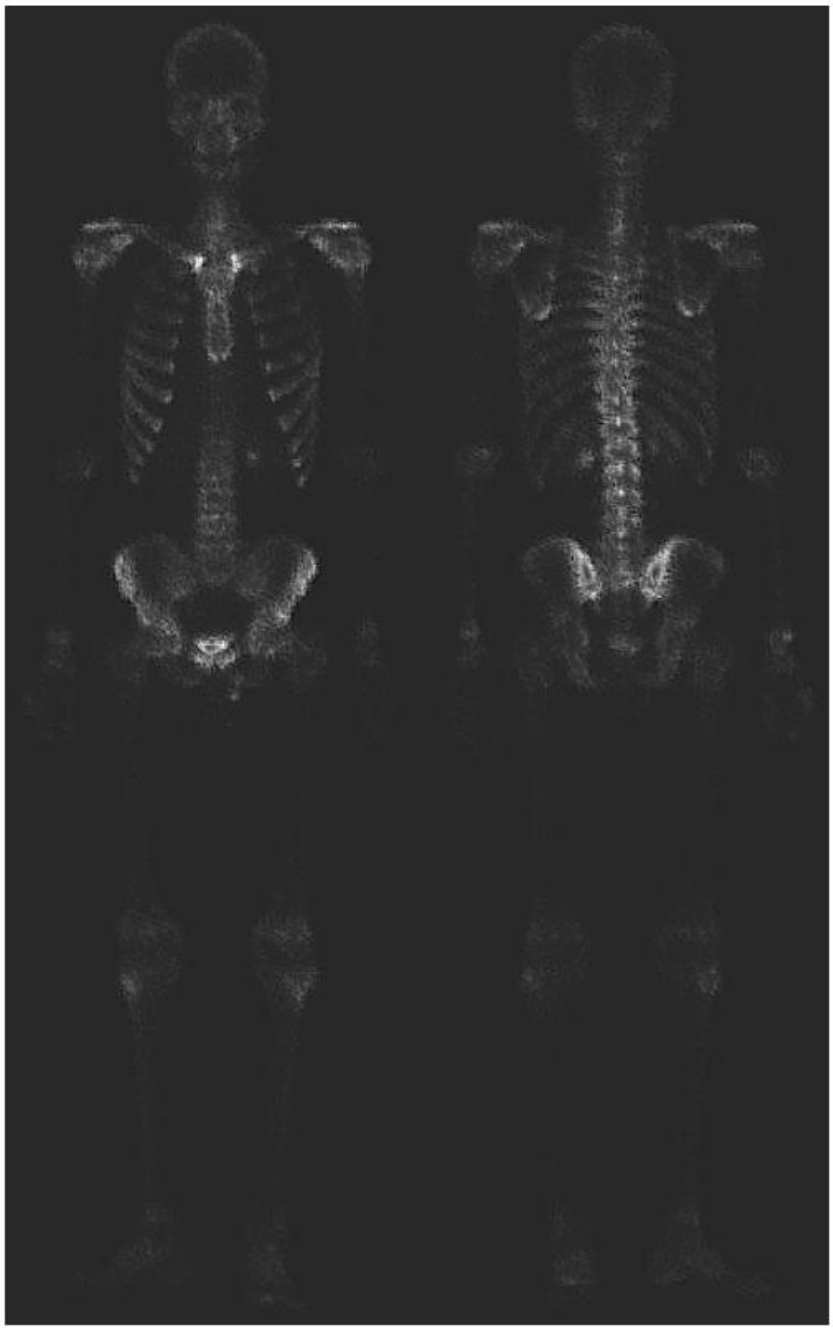

Figure 2.5: Laplacian Transform of skeleton_orig.tif

2.7 Image g

Adding the image f to the original image and then we get image g.
image g:

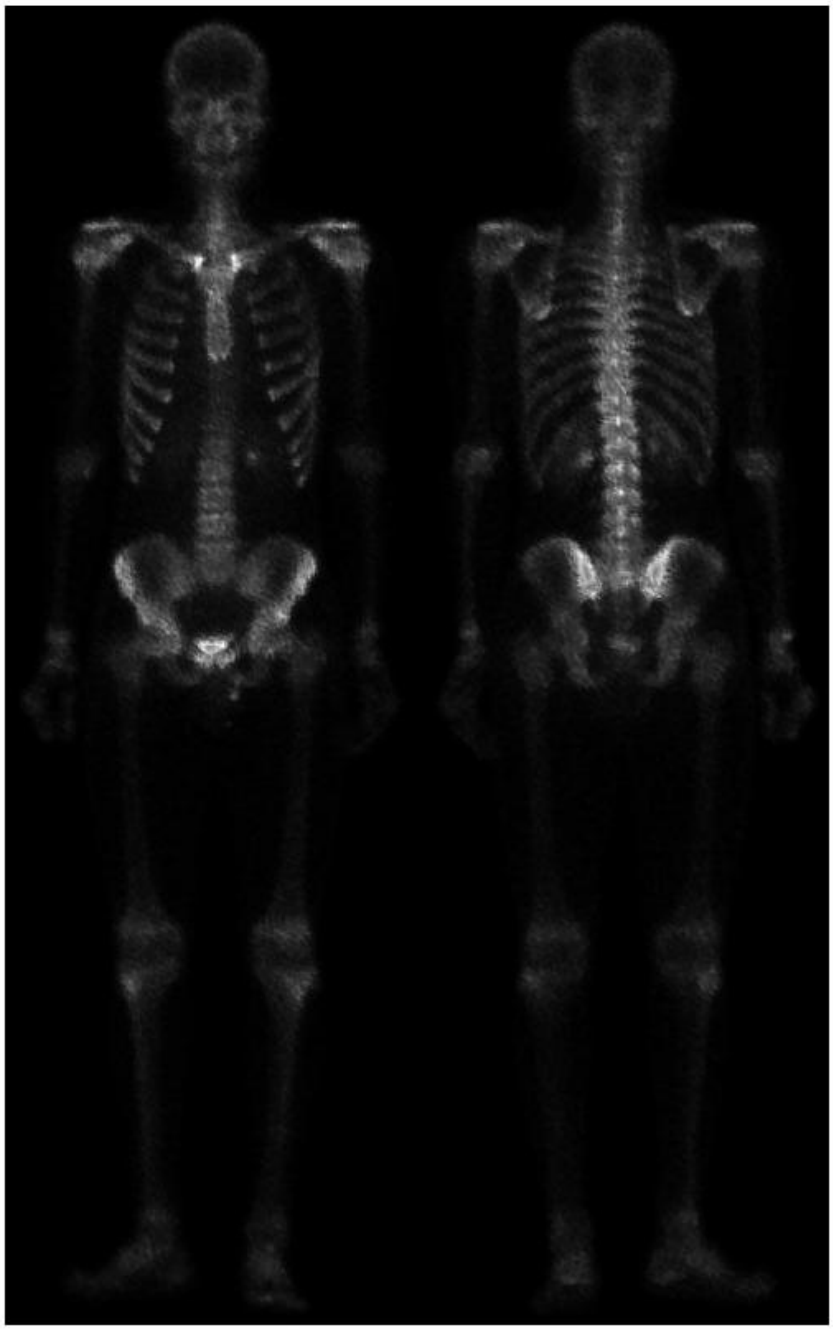

Figure 2.6: Laplacian Transform of skeleton_orig.tif

2.8 Image h

2.8.1 Power-Law Transformation

We use the following function to perform Power-Law Transformation on image g.

$$s = cr^{\gamma} \ (c \ = \ 1 \ and \ \gamma \ = \ 1) \tag{2.1}$$

2.8.2 Image h

Image h:

Figure 2.7: Laplacian Transform of skeleton_orig.tif

3.1 OverView

Implement the ideal, Butterworth and Gaussian lowpass and highpass filters and compare the results under different parameters using the image characters_test_pattern.tif (this image file can be found at the ftp server ftp://ftp.cs.sjtu.edu.cn:990/lu-ht/DIP/images) as the test pattern.

3.2 Fourier Transform

3.2.1 Transform Function

We ⊠rst need transform the image to gray image and then use the 2D Fourier transformation belw to change it to the frequence domain.

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi(\frac{ux}{M}+\frac{vy}{N})} \tag{3.1}$$

$$f(x,y) = \frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v)e^{j2\pi(\frac{ux}{M}+\frac{vy}{N})} \tag{3.2}$$

3.2.2 Fast Fourier Transform

The inverse funtion of FFT is as folows:

$$F(u+\frac{M}{2}, v+\frac{N}{2}) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi(\frac{ux+x\frac{M}{2}}{M}+\frac{vy+v\frac{N}{2}}{N})} \tag{3.3}$$

$$= \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)e^{-j2\pi(\frac{ux}{M}+\frac{vy}{N})} * e^{-j\pi x} * e^{-j\pi y} \tag{3.4}$$

$$= \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} -1^{x+y} f(x,y)e^{-j2\pi(\frac{ux}{M}+\frac{vy}{N})} \tag{3.5}$$

3.3 Filtering

- Expand image$(M*N)$ to image a$((2*M)*(2*N))$
- Perform the fourier transform on the new image and get image b
- Shift image b and get image c
- Perform the convolution on image c and filter and get image d
- Shift image d back and get image e
- Perform the inverse fourier transform on image e and get image f
- Cut image f to get the final result image$(M*N)$;

3.4 Ideal Filter

3.4.1 Ideal Low Pass

Ideal Low Pass Filter

The ideal low pass filter is defined as follows:

$$H(u,v) = \begin{cases} 1, & D(u,v) \leq 0 \\ 0, & D(u,v) > 0 \end{cases} \tag{3.6}$$

$$D(u,v) = \sqrt{[(u - \frac{P}{2})^2 + (v - \frac{Q}{2})^2]} \tag{3.7}$$

Result

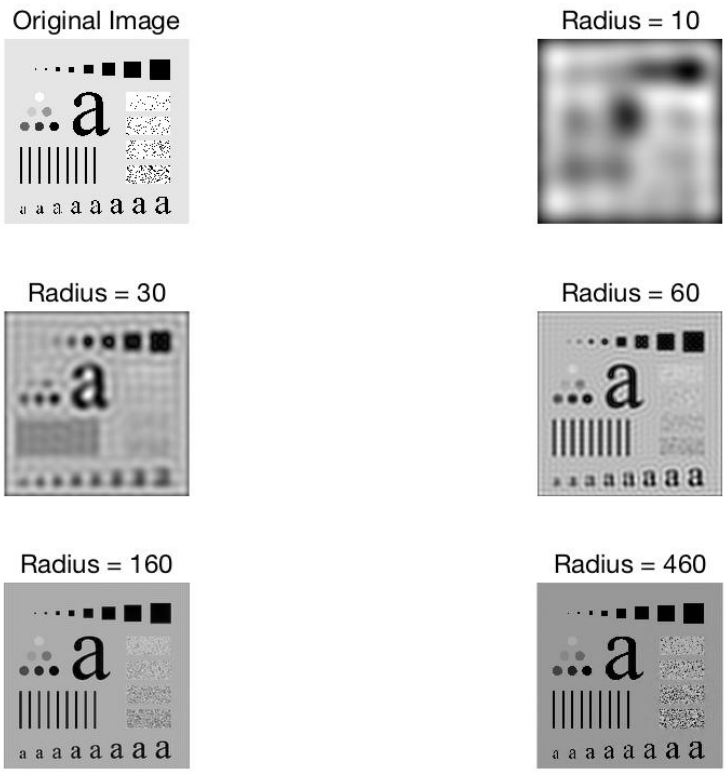

Figure 3.1: ILPF of characters_test_pattern.tif

3.4.2 Ideal High Pass

Ideal High Pass Filter

The ideal high pass filter is defined as follows:

$$H(u,v) = \begin{cases} 0, & D(u,v) \leq 0 \\ 1, & D(u,v) > 0 \end{cases} \tag{3.8}$$

$D(u,v)$ is defined in (3.7)

Result

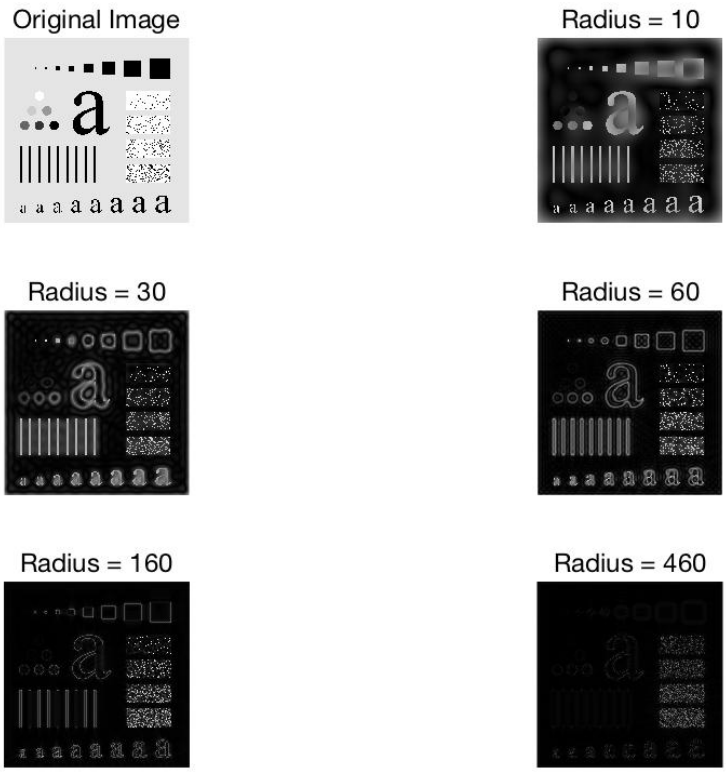

Figure 3.2: ILPF of characters_test_pattern.tif

3.5 Butterworth Filter

3.5.1 Butterworth Low Pass

Butterworth Low Pass Filter

The butterworth low pass filter is defined as follows:

$$H(u,v) = \frac{1}{1+[D(u,v)/D_0]^{2n}} \tag{3.9}$$

$D(u,v)$ is defined in (3.7)

Result

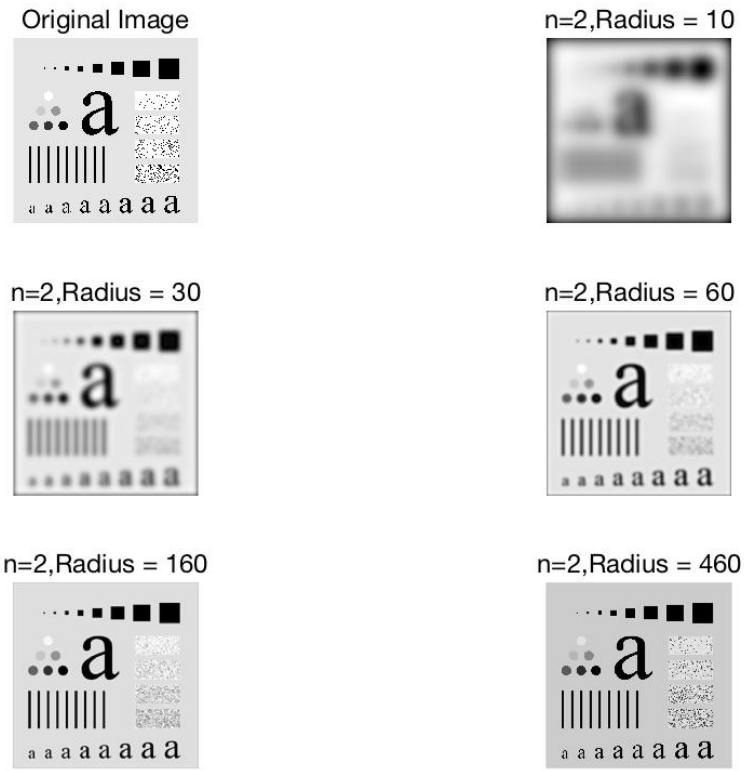

Figure 3.3: BLPF of characters_test_pattern.tif

3.5.2 Butterworth High Pass

Butterworth High Pass Filter

The butterworth high pass filter is defined as follows:

$$H(u,v) = \frac{1}{1+[D_0/D(u,v)]^{2n}} \tag{3.10}$$

$D(u, v)$ is defined in (3.7)

Result

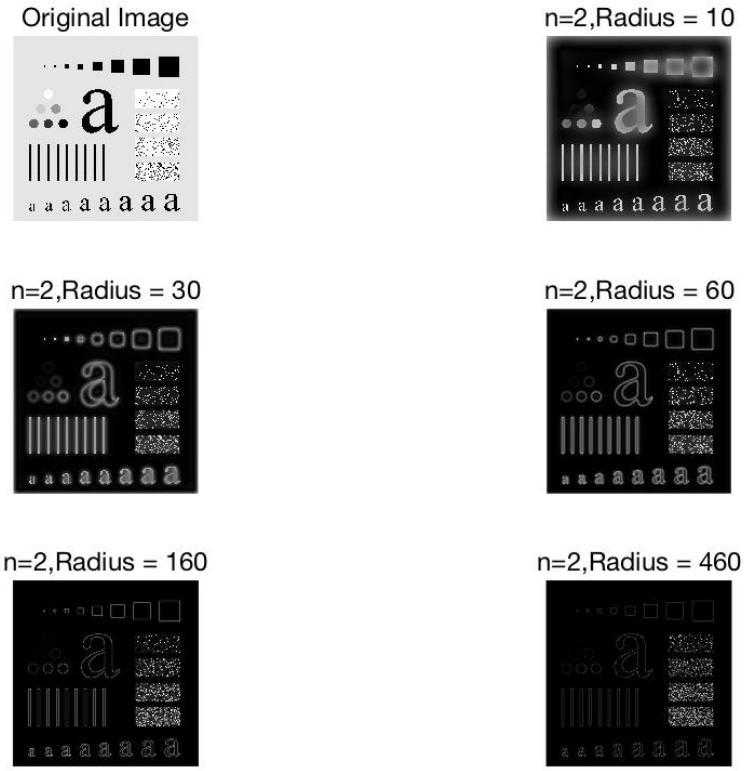

Figure 3.4: BLPF of characters_test_pattern.tif

3.6 Gaussian Filter

3.6.1 Gaussian Low Pass

Gaussian Low Pass Filter

The gaussian low pass filter is defined as follows:

$$H(u,v) = e^{-\frac{D^2(u,v)}{2\sigma^2}} \tag{3.11}$$

$D(u,v)$ is defined in (3.7)

Result

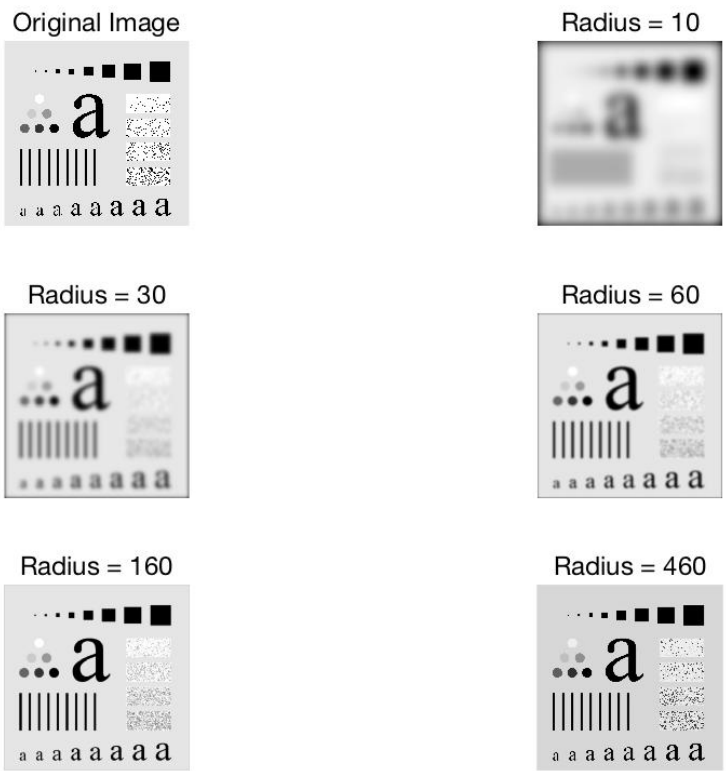

Figure 3.5: GLPF of characters_test_pattern.tif

3.6.2 Gaussian High Pass

Gaussian High Pass Filter

The gaussian high pass filter is defined as follows:

$$H(u,v) = 1 - e^{-\frac{D^2(u,v)}{2\sigma^2}} \tag{3.12}$$

$D(u,v)$ is defined in (3.7)

Result

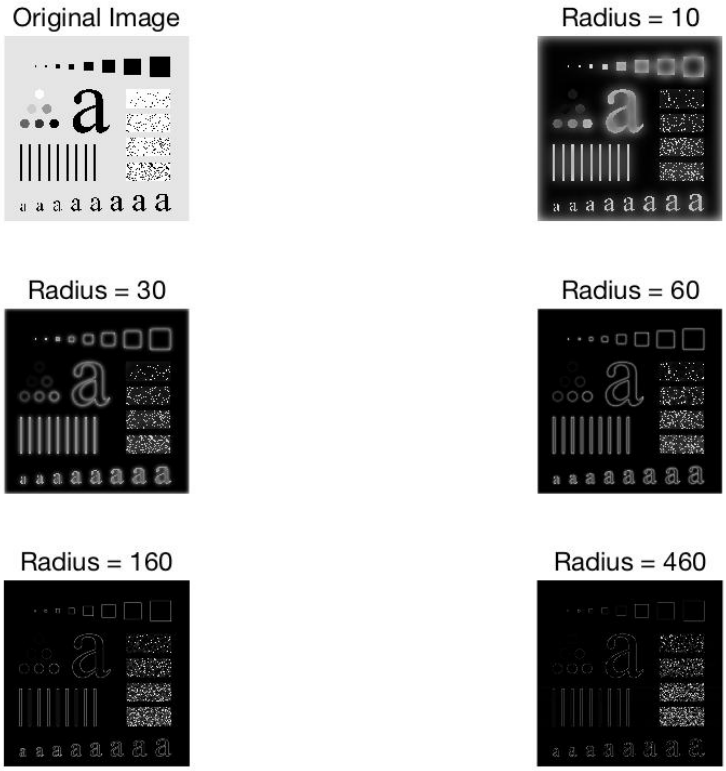

Figure 3.6: GLPF of characters_test_pattern.tif

4.1 OverView

In this problem, you are required to write a program to generate different types of random noise (Uniform, Gaussian, Rayleigh, Gamma, Exponential and Impulse, first started from the uniform noise and then use some functions to convert the uniform noise to Gaussian, Rayleigh, Gamma and Exponential; Impulse noise is generated in a different way, consulting the textbook and some other references) and then add these noises to the test patter image Fig0503(original_pattern).tif to compare the visual results of the noisy images.
Add some of these noises to the circuit image Circuit.tif (images can be found at ftp://ftp.cs.sjtu.edu.cn:990/lu-ht/DIP/images) and investigate the noise reduction results using different mean filters and order statistics filters as the textbook did at pages 344-352 (Pages 322-329 in the electronic version of the textbook).

4.2 Noise

4.2.1 Uniform Noise

The PDF of $uniformnoise$ is given by

$$p(z) = \begin{cases} \frac{1}{b-a}, & if\ a \leq z \leq b \\ 0, & otherwise \end{cases} \tag{4.1}$$

The mean of this density function is given by

$$\overline{z} = \frac{a+b}{2} \tag{4.2}$$

and its variance by

$$\sigma^2 = \frac{(b-a)^2}{12} \tag{4.3}$$

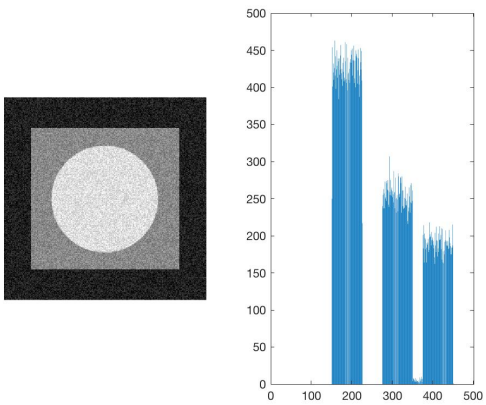

Figure 4.1: Uniform Noise

4.2.2 Gaussian Noise

The PDF of a $Gaussian$ random variable, z, is given by

$$p(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(z-\bar{z})^2}{z\sigma^2}} \tag{4.4}$$

and it can generate form uniform noise by

$$X = \sqrt{-2lnU} cos(2\pi V) \tag{4.5}$$
$$Y = \sqrt{-2lnU} sin(2\pi V) \tag{4.6}$$

U and V come form uniform(0,1).

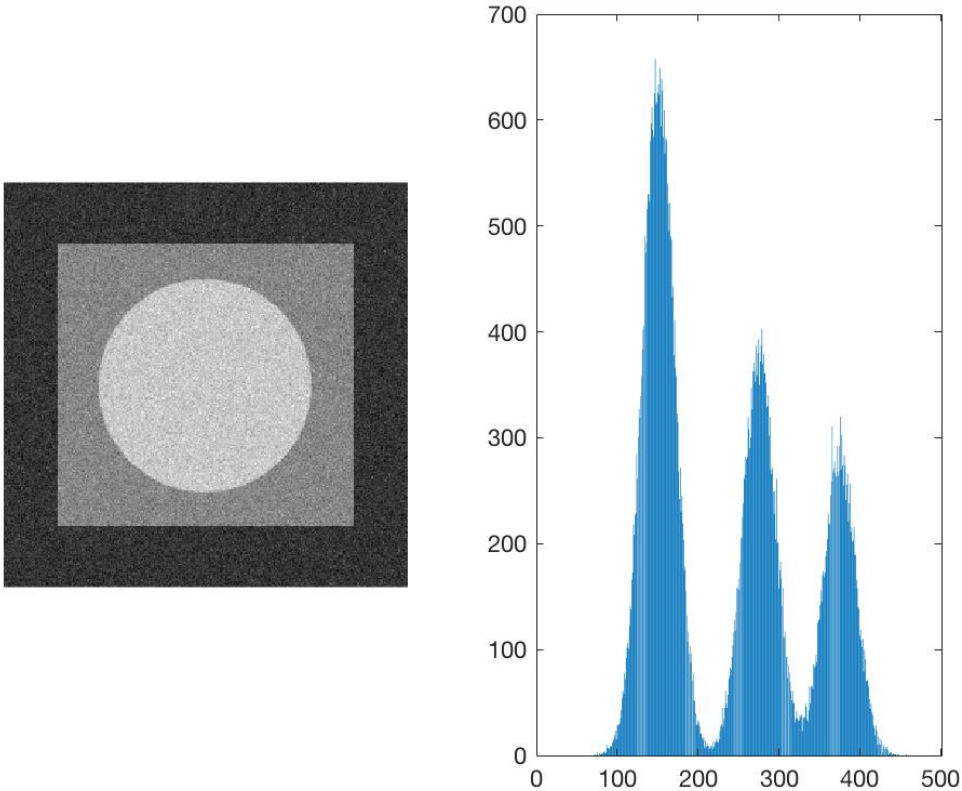

Figure 4.2: Gaussian Noise

4.2.3 Rayleigh Noise

The PDF of $Rayleighnoise$ is given by

$$p(z) = \begin{cases} \frac{2}{b}(z-a)e^{-\frac{(z-a)^2}{b}}, & for\ z \geq a \\ 0, & for\ z < a \end{cases} \tag{4.7}$$

The mean and variance of this density are given by

$$\overline{z} = a + \sqrt{\frac{b\pi}{4}} \tag{4.8}$$

and

$$\sigma^2 = \frac{b(4-\pi)}{4} \tag{4.9}$$

and it can generate form uniform noise by

$$z = a + \sqrt{-bln[1-U(0,1)]} \tag{4.10}$$

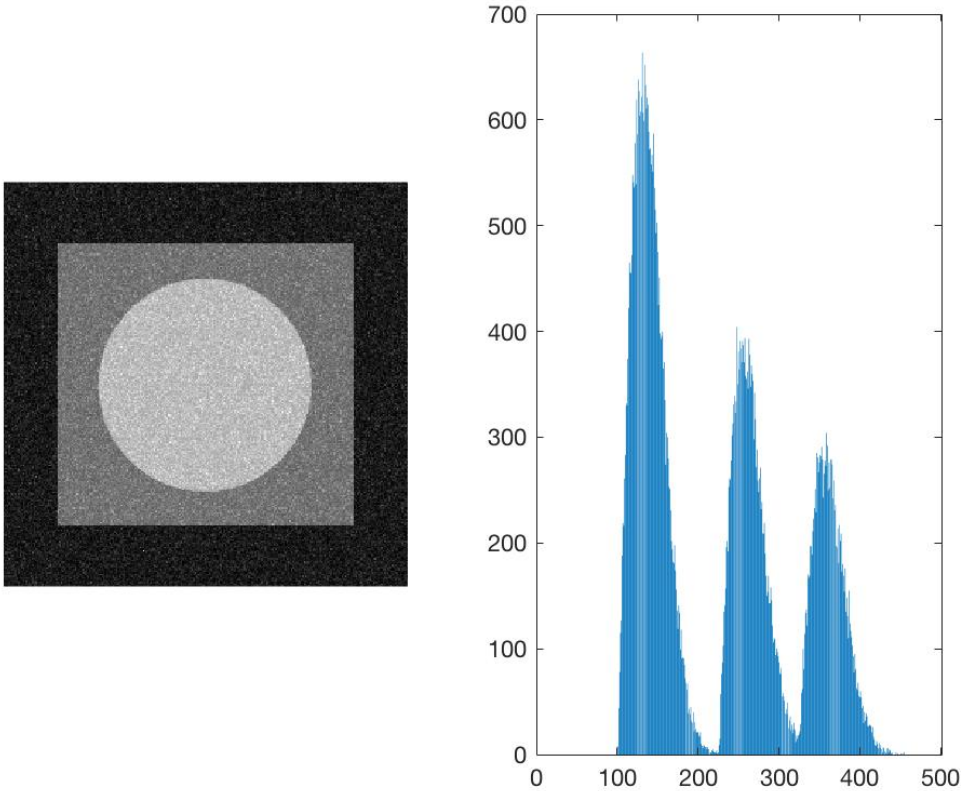

Figure 4.3: Rayleigh Noise

4.2.4 Erlang(Gamma) Noise

The PDF of $Erlangnoise$ is given by

$$p(z) = \begin{cases} \frac{a^b z^{b-1}}{(b-1)!} e^{-az}, & for\ z \geq 0 \\ 0, & for\ z < 0 \end{cases} \tag{4.11}$$

The mean and variance of this density are given by

$$\overline{z} = \frac{b}{a} \tag{4.12}$$

and

$$\sigma^2 = \frac{b}{a^2} \tag{4.13}$$

and it can generate form uniform noise by

$$E_i = -\frac{1}{a} ln[1 - U(0,1)] \tag{4.14}$$

$$z = E_1 + E_2 + \cdots + E_b \tag{4.15}$$

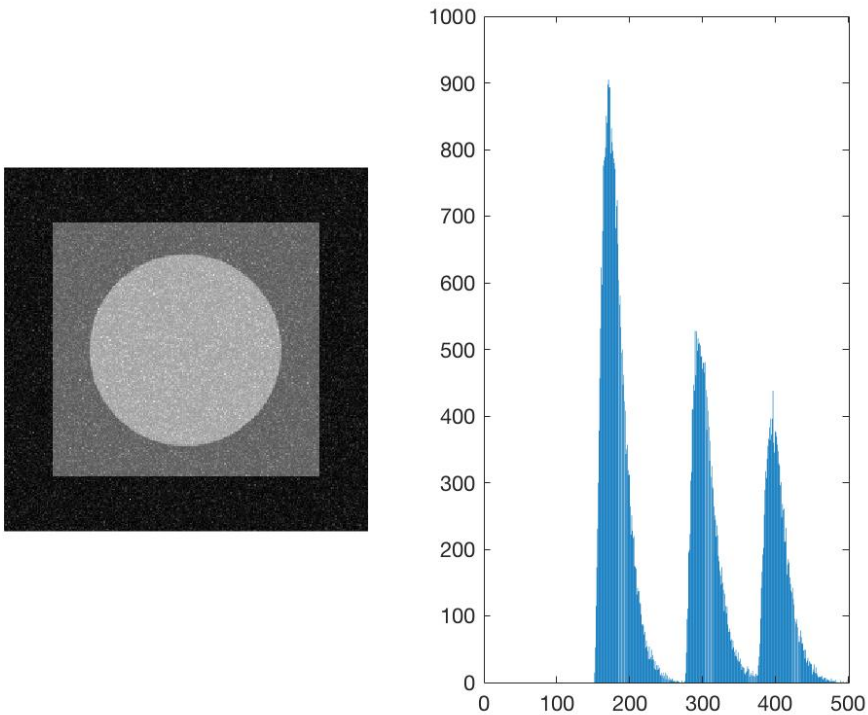

Figure 4.4: Gamma Noise

4.2.5 Exponential Noise

The PDF of $exponentialnoise$ is given by

$$p(z) = \begin{cases} ae^{-az}, & for\ z \geq 0 \\ 0, & for\ z < 0 \end{cases} \tag{4.16}$$

The mean and variance of this density function are

$$\overline{z} = \frac{1}{a} \tag{4.17}$$

and

$$\sigma^2 = \frac{1}{a^2} \tag{4.18}$$

and it can generate form uniform noise by

$$z = -\frac{1}{a} ln[1 - U(0,1)] \tag{4.19}$$

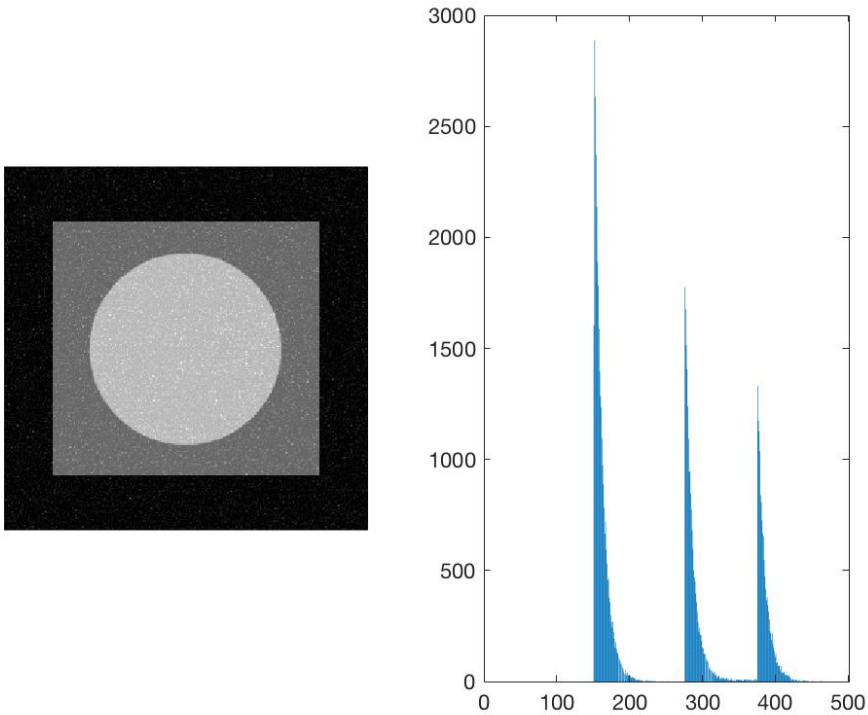

Figure 4.5: Exponential Noise

4.2.6 Impulse Noise

The PDF of $(bipolar)impulsenoise$ is given by

$$p(z) = \begin{cases} P_a, & for\ z = a \\ P_b, & for\ z = b \\ 0, & otherwise \end{cases} \tag{4.20}$$

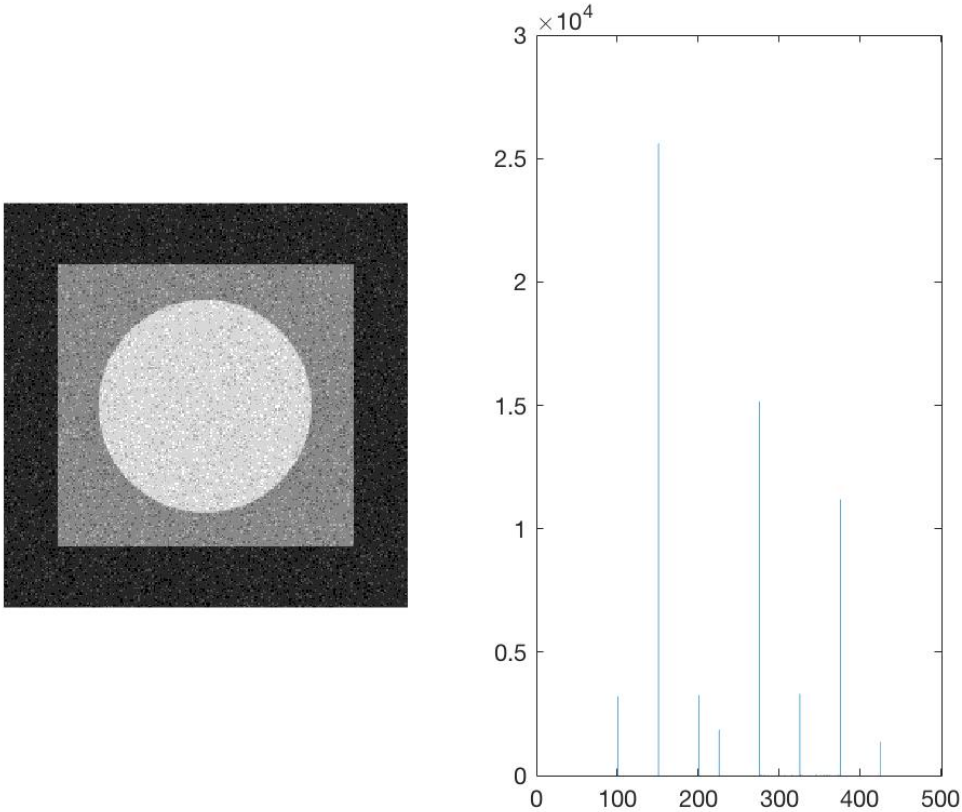

Figure 4.6: Impulse Noise

4.3 Mean Filters

4.3.1 Filters

Arithmetic mean filter

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t) \tag{4.21}$$

Geometric mean filter

$$\hat{f}(x,y) = [\prod_{(s,t)\in S_{xy}} g(s,t)]^{\frac{1}{mn}} \tag{4.22}$$

Harmonic mean filter

$$\hat{f}(x,y) = \frac{mn}{\sum_{(s,t)\in S_{xy}} \frac{1}{g(s,t)}} \tag{4.23}$$

Contraharmonic mean filter

$$\hat{f}(x,y) = \frac{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q+1}}{\sum_{(s,t)\in S_{xy}} g(s,t)^{Q}} \tag{4.24}$$

4.3.2 Results

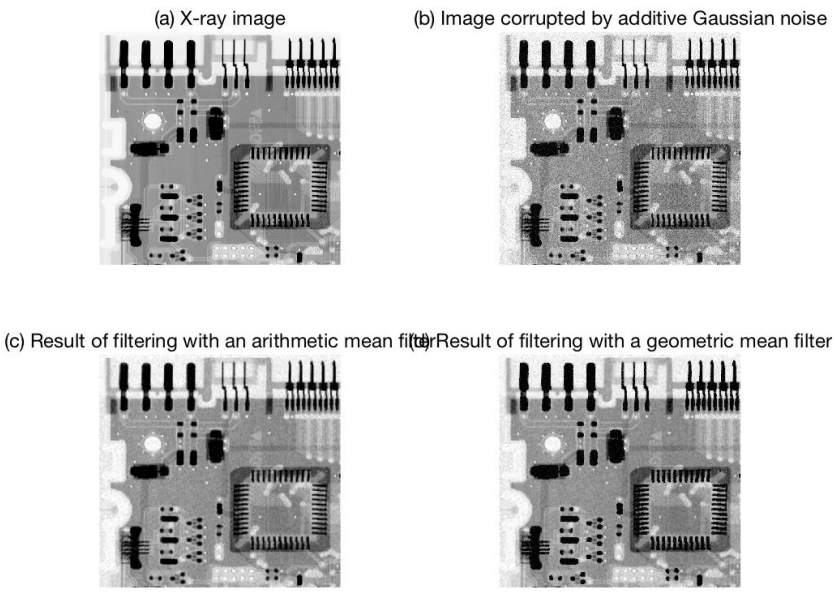

Figure 4.7: Original Book FIGURE 5.7

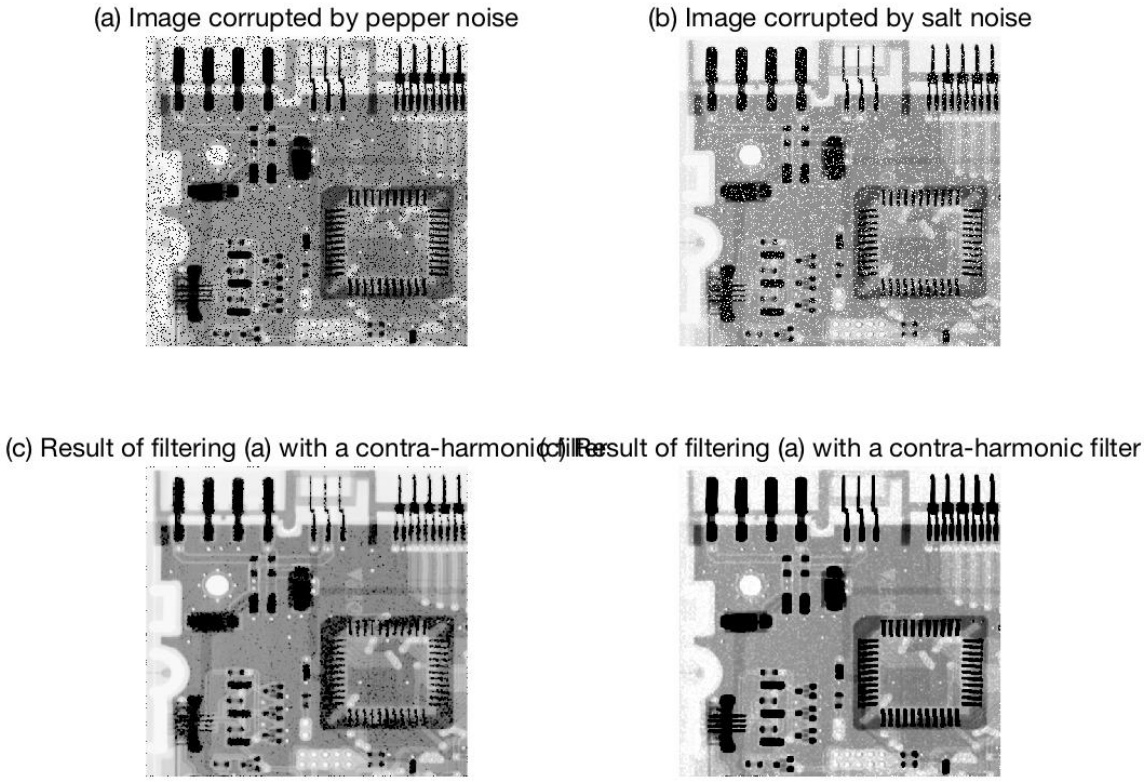

Figure 4.8: Original Book FIGURE 5.8

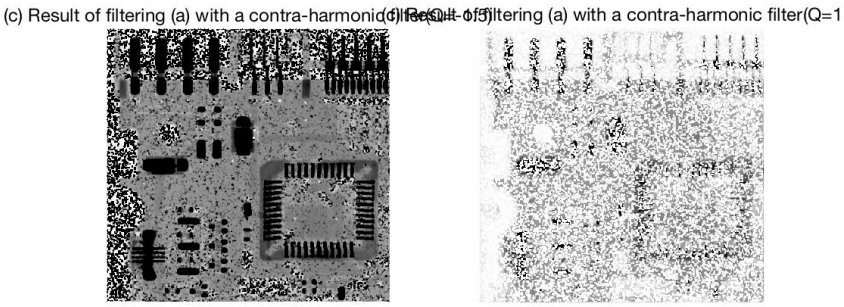

Figure 4.9: Original Book FIGURE 5.9

4.4 Order-Statistic Filters

4.4.1 Filters

Median filter

$$\hat{f}(x,y) = median_{(s,t)\in S_{xy}} g(s,t) \tag{4.25}$$

Max filters

$$\hat{f}(x,y) = max_{(s,t)\in S_{xy}} g(s,t) \tag{4.26}$$

Min filters

$$\hat{f}(x,y) = min_{(s,t)\in S_{xy}} g(s,t) \tag{4.27}$$

Midpoint filter

$$\hat{f}(x,y) = \frac{1}{2}[max_{(s,t)\in S_{xy}} g(s,t) + min_{(s,t)\in S_{xy}} g(s,t)] \tag{4.28}$$

Alpha-trimmed mean filter

$$\hat{f}(x,y) = \frac{1}{mn-d} \sum_{(s,t)\in S_{xy}} g_r(s,t) \tag{4.29}$$

4.4.2 Results

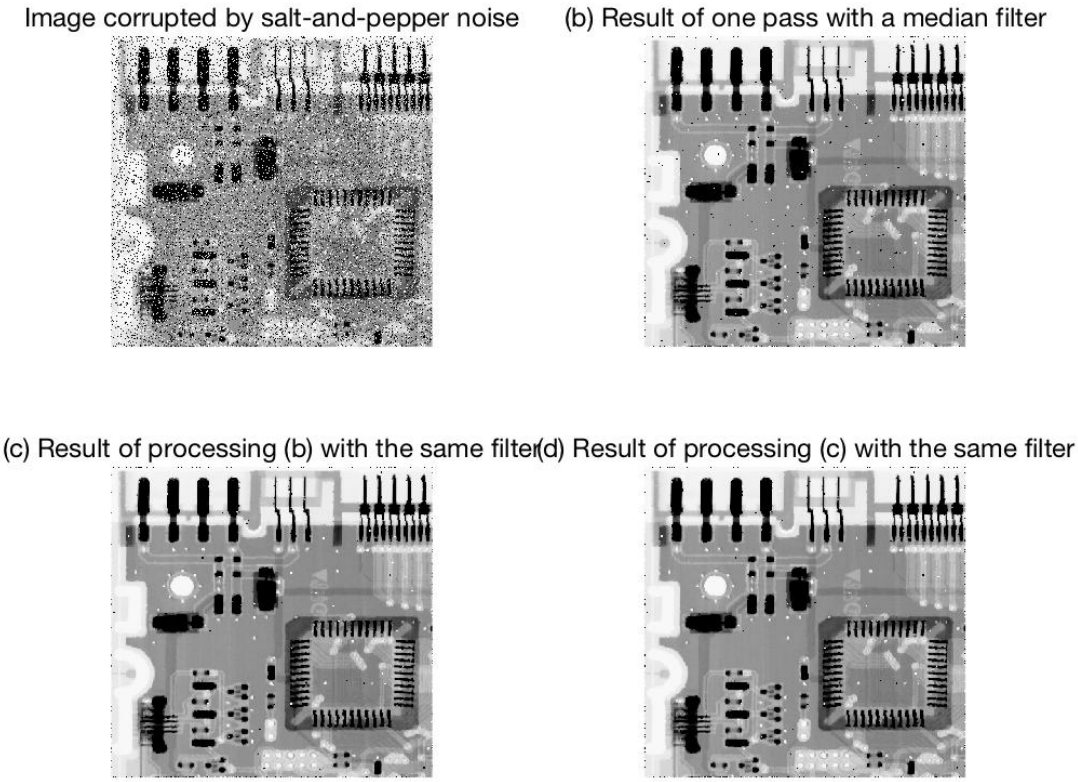

Figure 4.10: Original Book FIGURE 5.10

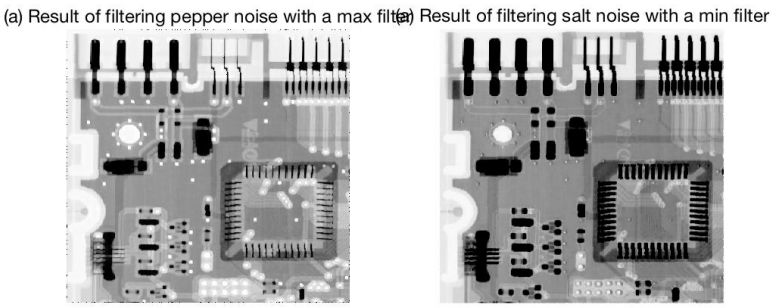

Figure 4.11: Original Book FIGURE 5.11

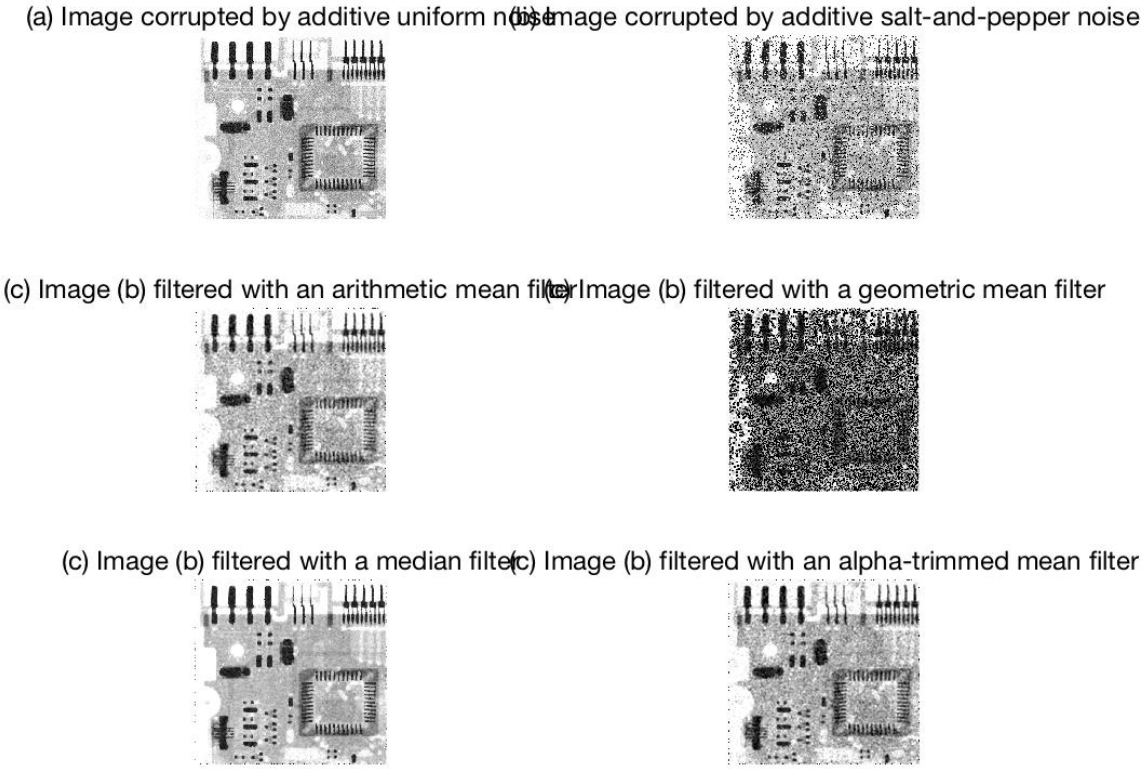

Figure 4.12: Original Book FIGURE 5.12

5.1 OverView

Suppose a blurring degradation function as

$$H(u,v) = \frac{T}{\pi(ua+vb)} sin(\pi(ua+vb))e^{-j\pi(ua+vb)} \tag{5.1}$$

1. Implement a blurring filter using Eq. (5.1).
2. Blur the test image book_cover.jpg using parameters $a = b = 0.1$ and $T = 1$.
3. Add Gaussian noise of 0 mean and variance of 650 to the blurred image.
4. Restore the blurred image and the blurred noisy image using the inverse filter, Wiener filter, respectively.
5. Add Gaussian noise of 0 and different variances to the blurred image and repeat 4, investigate the performance of the Wiener filter.

5.2 Fliter

5.2.1 Motion Filter

Assume that we know $x_0(t)$, $y_0(t)$, and the image is moving in x-axis and y-axis moving according to the $x_0(t) = \frac{at}{T}$, $y_0(t) = \frac{bt}{T}$. Then we know:

$$H(u,v) = \frac{T}{\pi(ua+vb)} sin(\pi(ua+vb))e^{-j\pi(ua+vb)} \tag{5.2}$$

5.2.2 Inverse Filter

$$\hat{F}(u,v) = \frac{G(u,v)}{H(u,v)} \tag{5.3}$$

With noise:

$$\hat{F}(u,v) = F(u,v) + \frac{N(u,v)}{H(u,v)} \tag{5.4}$$

5.2.3 Wiener Filter

$$\hat{F}(u,v) = [\frac{1}{H(u,v)} \frac{|H(u,v)|^2}{|H(u,v)|^2 + K}]G(u,v) \tag{5.5}$$

5.3 Results

We can easily find that the performance of wiener filter is much better than inverse filter, and less the variance of the noise is, better the performance of the winner is.

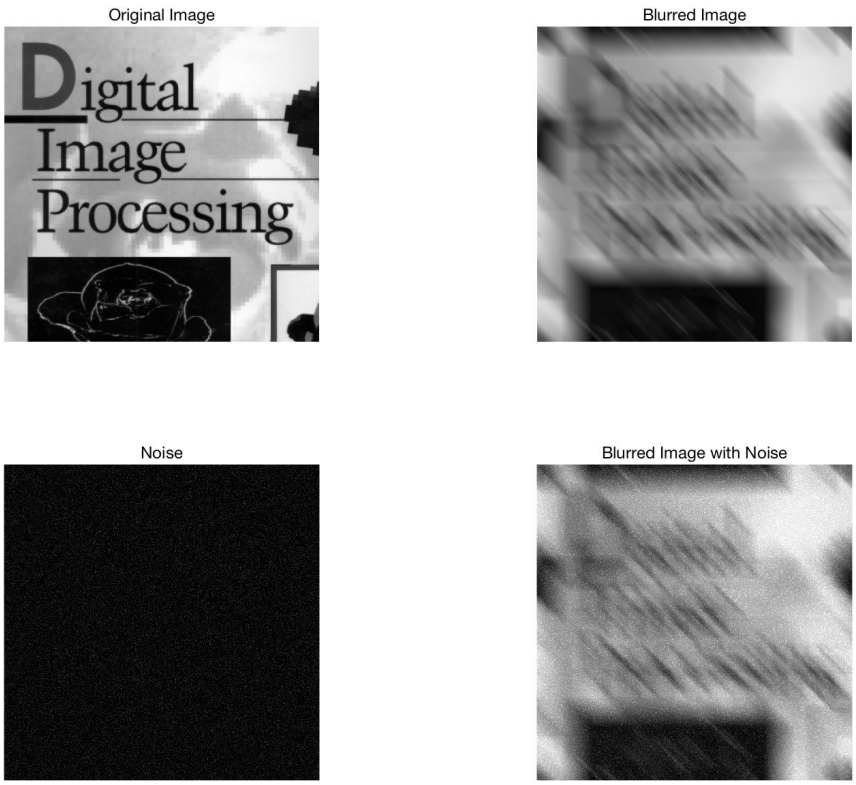

Figure 5.1: Blurred and Noise Image

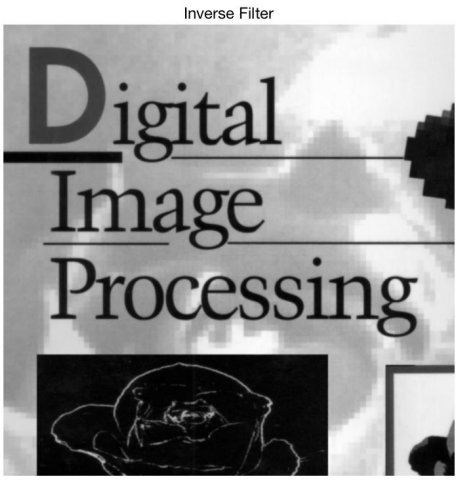

Figure 5.2: Restoration Image using Inverse Filter

Figure 5.3: Blurred Image with Noise(variance of 650)

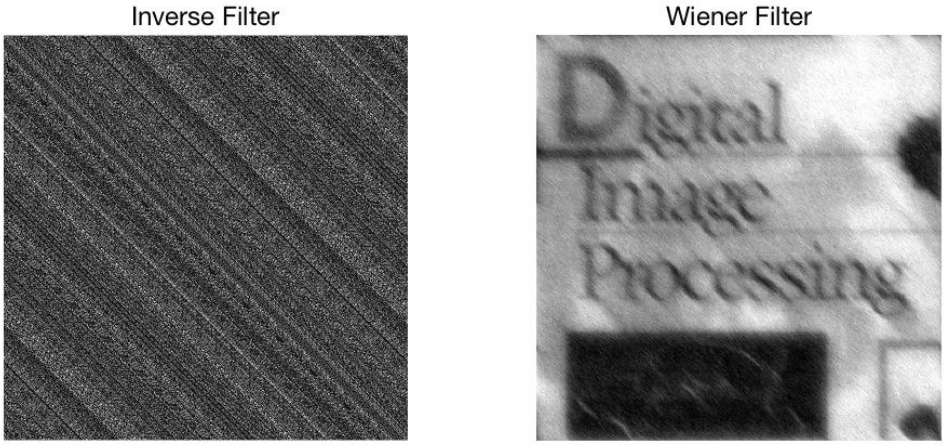

Figure 5.4: Restoration Image with Noise(variance of 650)

Figure 5.5: Blurred Image with Noise(variance of 324)

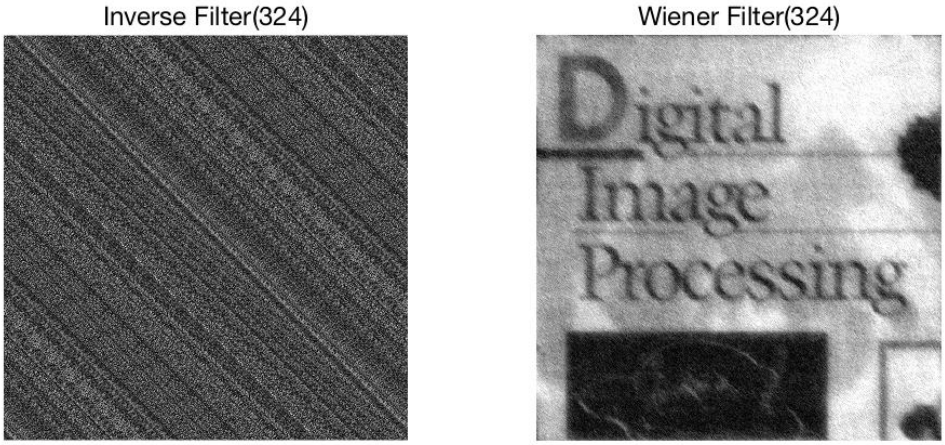

Figure 5.6: Restoration Image with Noise(variance of 324)

6.1 OverView

Develop a geometric transform program that will rotate, translate, and scale an image by specified amounts, using the nearest neighbor and bilinear interpolation methods, respectively.

6.2 Spatial Transformation

6.2.1 Rotate

(v, w) are pixel coordinates in the original image and (x, y) are the corresponding pixel coordinates in the transformed image

$$\begin{bmatrix} x & y & 1 \end{bmatrix} = \begin{bmatrix} v & w & 1 \end{bmatrix} T = \begin{bmatrix} v & w & 1 \end{bmatrix} \begin{bmatrix} cos\Theta & sin\Theta & 0 \\ -sin\Theta & cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{6.1}$$

6.2.2 Results

(a) Original Image

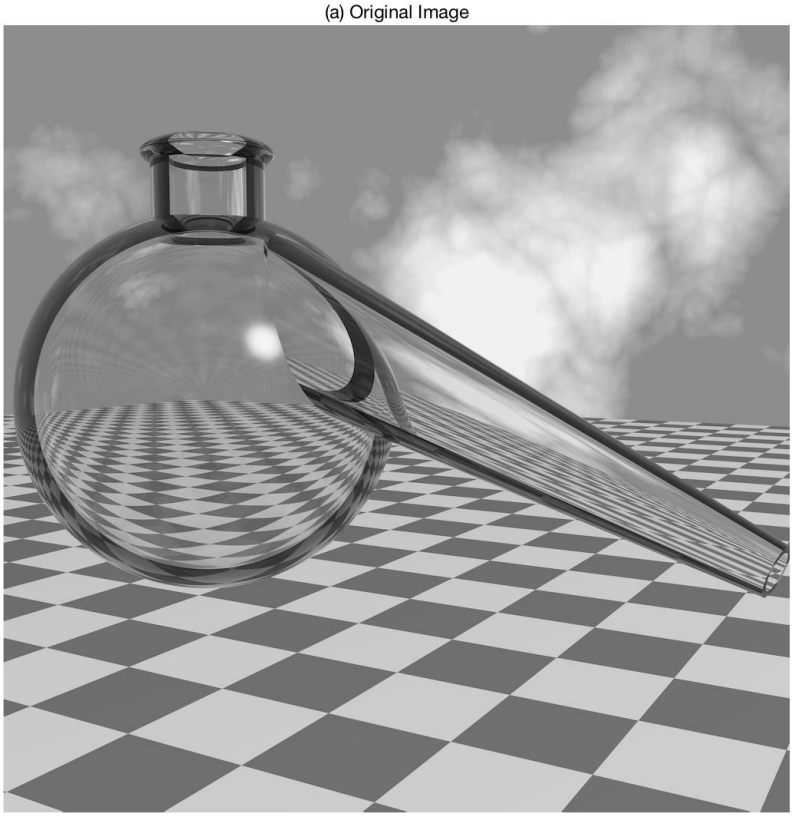

Figure 6.1: Original Image

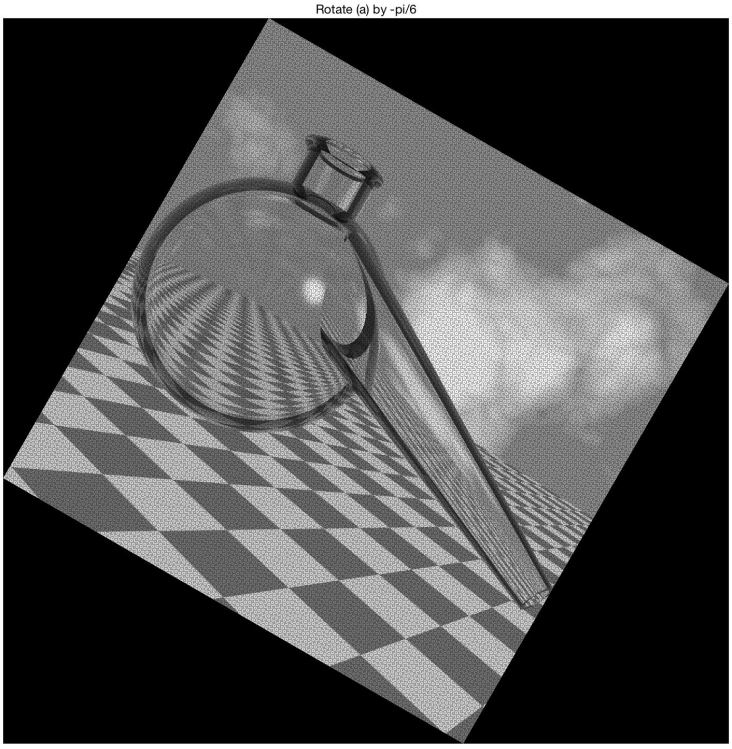

Figure 6.2: Rotate pi/6 without interpolation

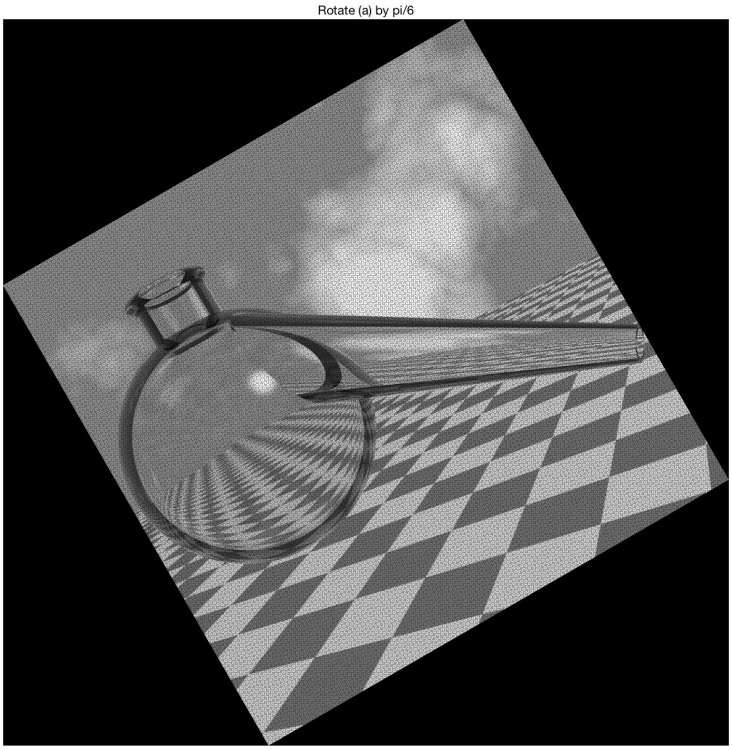

Figure 6.3: Rotate -pi/6 without interpolation

6.2.3 Translate

(v, w) are pixel coordinates in the original image and (x, y) are the corresponding pixel coordinates in the transformed image

$$\begin{bmatrix} x & y & 1 \end{bmatrix} = \begin{bmatrix} v & w & 1 \end{bmatrix} T = \begin{bmatrix} v & w & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix} \tag{6.2}$$

6.2.4 Results

(a) Original Image

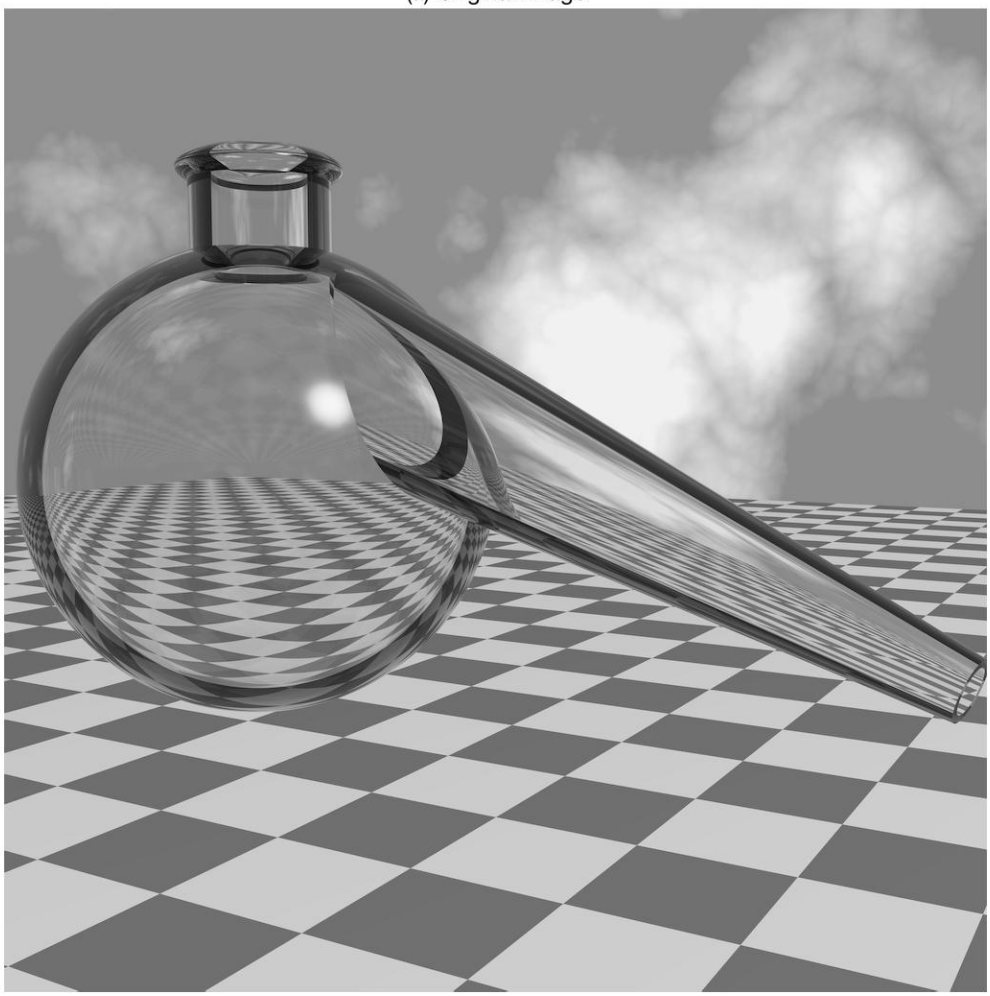

Figure 6.4: Original Image

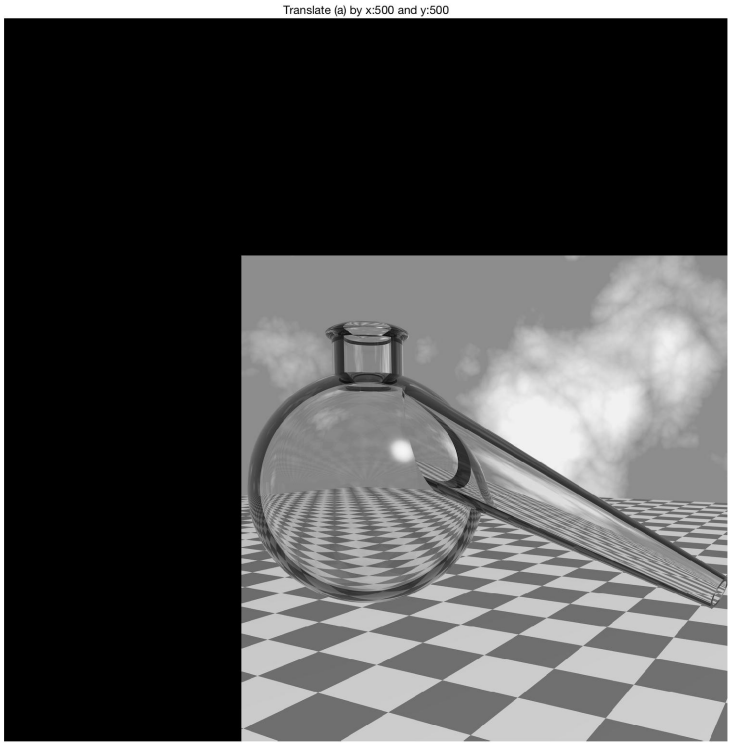

Figure 6.5: Translate X:500 and Y:500

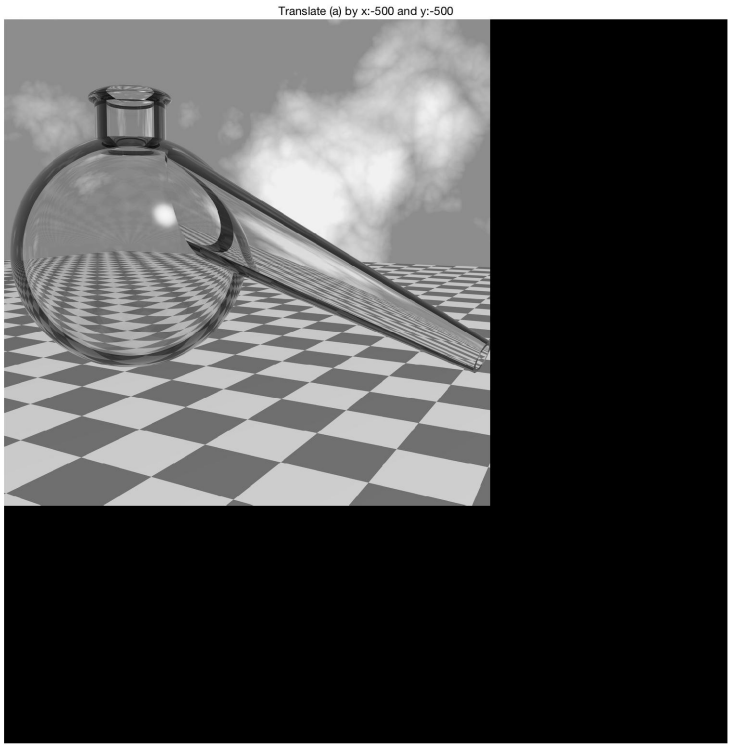

Figure 6.6: Translate X:-500 and Y:-500

6.2.5 Scaling

(v, w) are pixel coordinates in the original image and (x, y) are the corresponding pixel coordinates in the transformed image

$$\begin{bmatrix} x & y & 1 \end{bmatrix} = \begin{bmatrix} v & w & 1 \end{bmatrix} T = \begin{bmatrix} v & w & 1 \end{bmatrix} \begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{6.3}$$

6.2.6 Results

Since the original image is too large to show the detial change, I scale the original image to 0.25*0.25(b) and then scale (b) to 2*2.

(a) Original Image

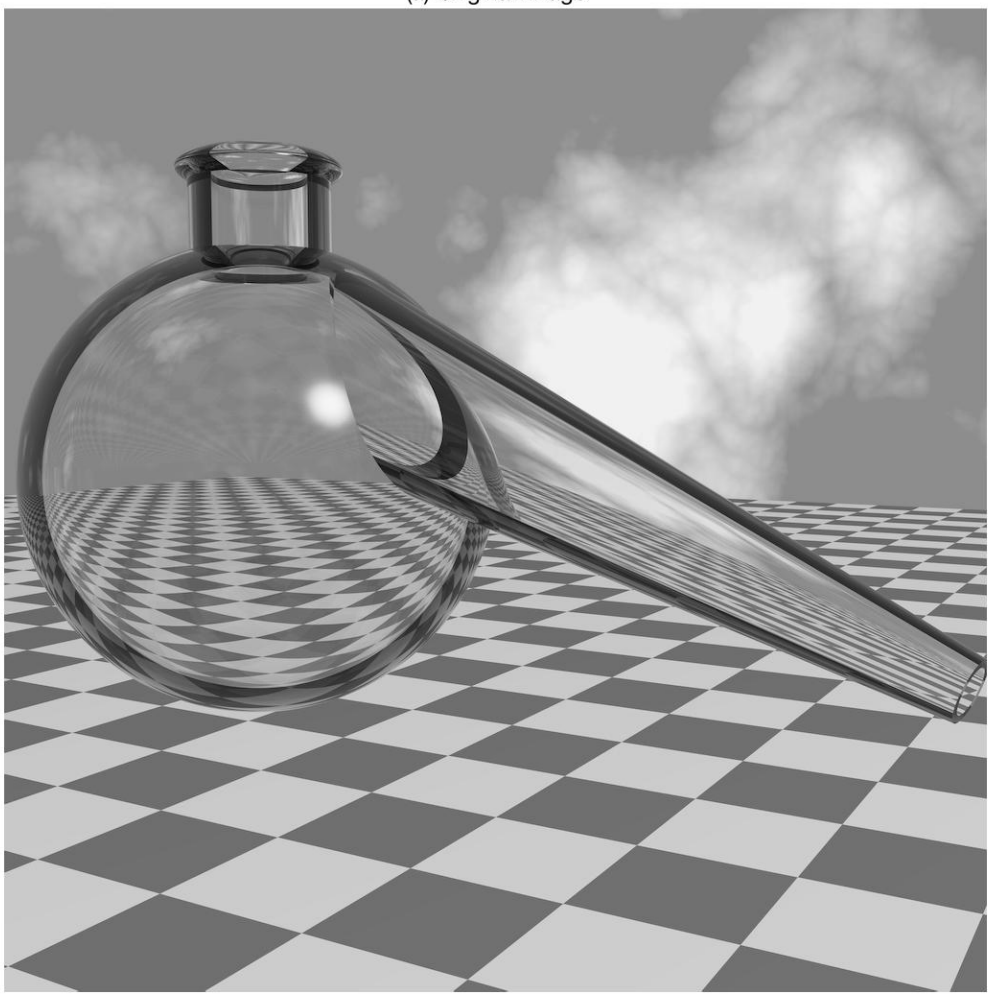

Figure 6.7: Original Image

(b) Scale (a) to 0.25*0.25

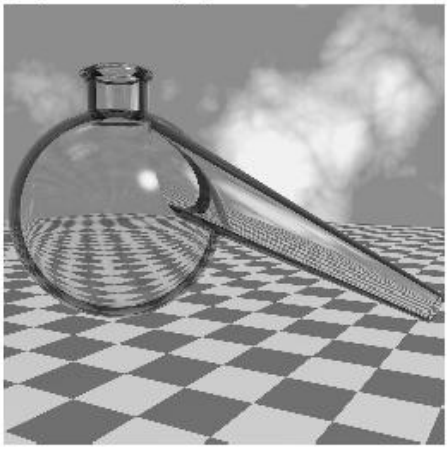

Figure 6.8: Scaling 0.25*0.25 without interpolation

Scale (b) to 2*2

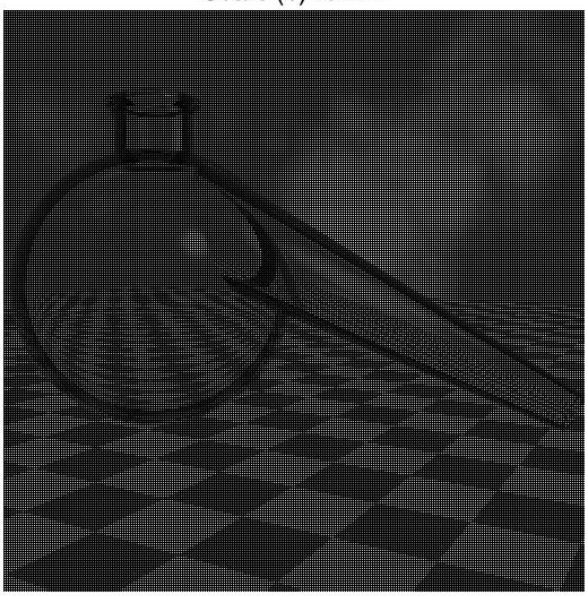

Figure 6.9: Scaling 2*2 without interpolation

6.3 Interpolation Methods

6.3.1 Methods

Nearest Neighbor Interpolation

We look for its closest pixel in the original image and assign the intensity of that pixel to the new pixel.

Bilinear Interpolation

We use the four nearest neighbors to estimate the intensity at a given location.

6.3.2 Results

Rotate (a) by pi/6 using nearest neighbor

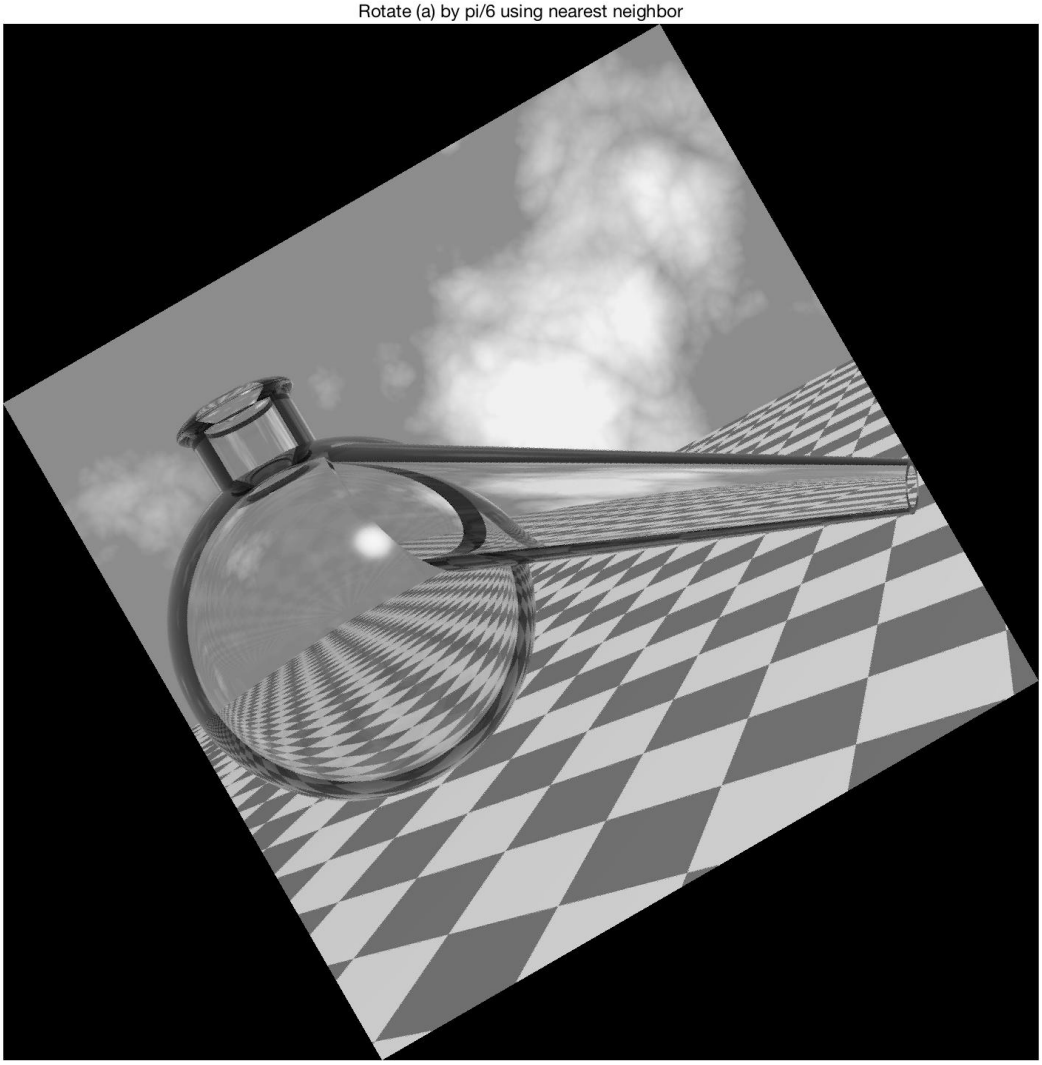

Figure 6.10: Rotate pi/6 using nearest neighbor interpolation

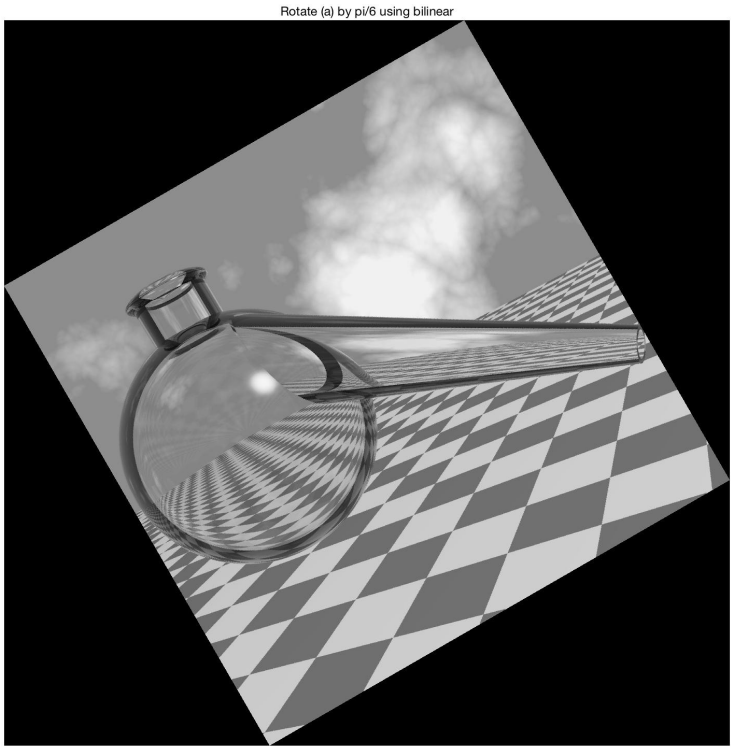

Figure 6.11: Rotate pi/6 using bilinear interpolation

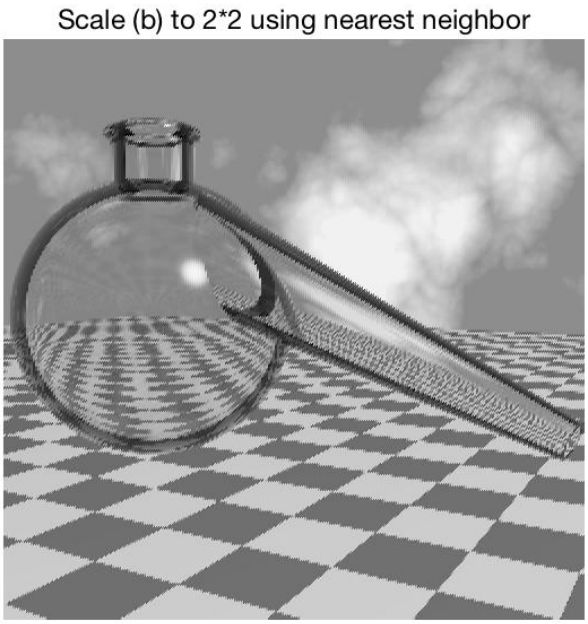

Figure 6.12: Scaling 2*2 using nearest neighbor interpolation

Scale (b) to 2*2 using bilinear

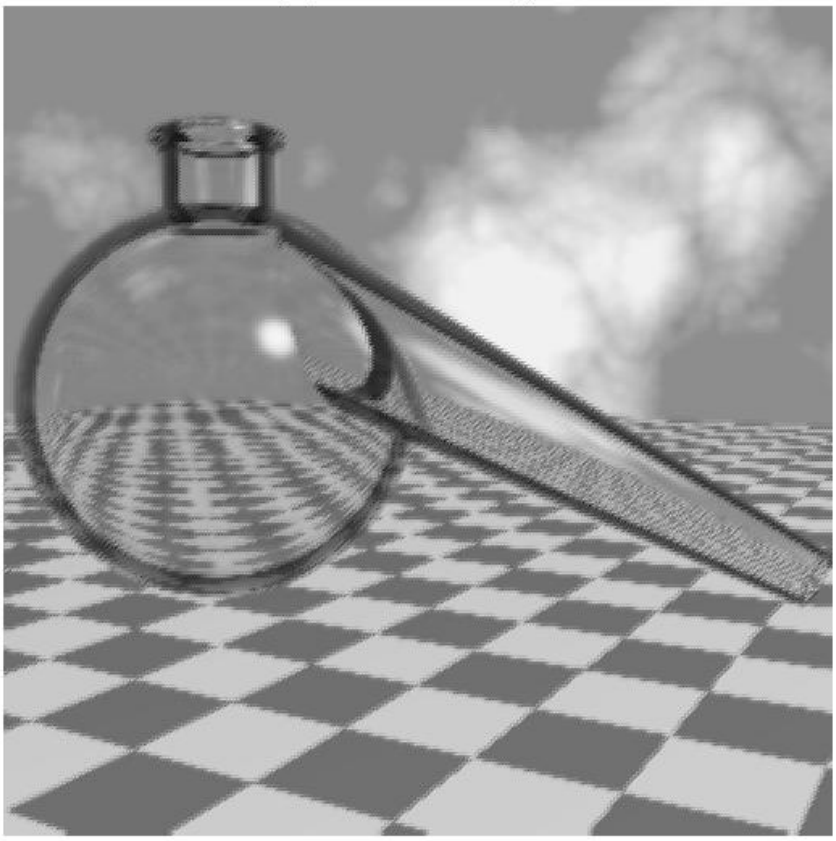

Figure 6.13: Scaling 2*2 using bilinear interpolation

7.1 OverView

Implement the "Opening by reconstruction", "Filling holes" and "Border clearing" operations on pages 681-683 (pp.659-661 for the electronic textbook), and reproduce the results in Figure 9.29, Figures 9.31, and Figure 9.32.

7.2 Erosion and Dilation

7.2.1 Erosion

With A and B as sets in Z^2 , the erosion of A by B, denoted $A \ominus B$, is defined as

$$A \ominus B = \{z|(B)_z \subseteq A\} \tag{7.1}$$

or

$$A \ominus B = \{z|(B)_z \cap A^c = \varnothing\} \tag{7.2}$$

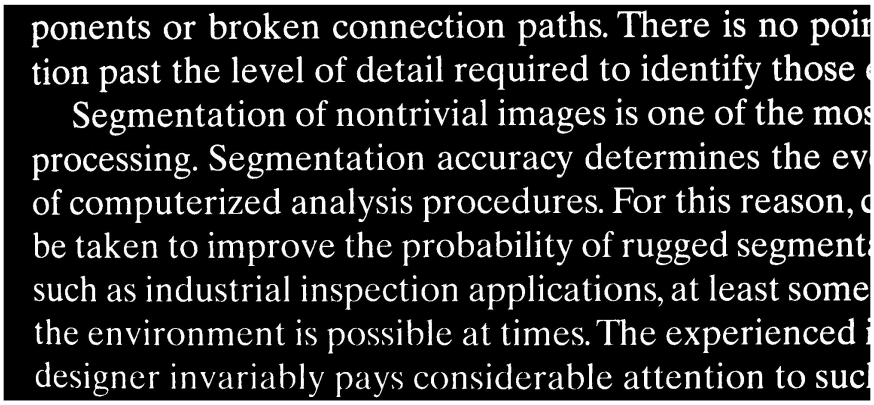
ponents or broken connection paths. There is no poi
tion past the level of detail required to identify those
Segmentation of nontrivial images is one of the mos
processing. Segmentation accuracy determines the ev
of computerized analysis procedures. For this reason,
be taken to improve the probability of rugged segment
such as industrial inspection applications, at least some
the environment is possible at times. The experienced
designer invariably pays considerable attention to suc

Figure 7.1: Original Image

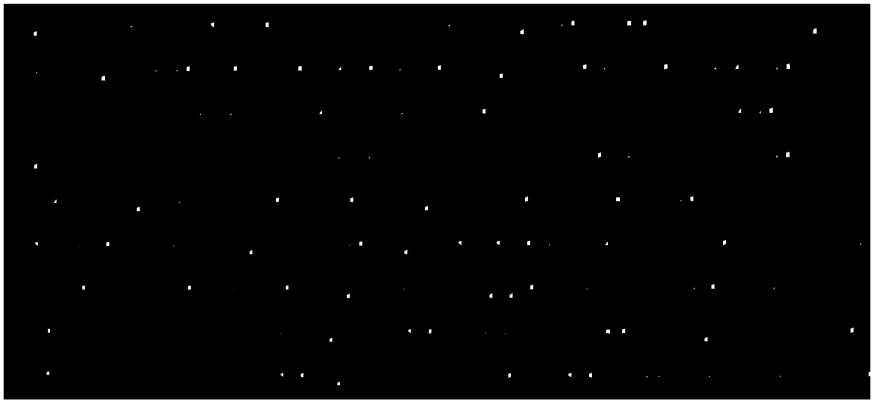

Figure 7.2: Erosion of Figure 7.1

7.2.2 Dilation

With A and B as sets in Z^2 , the erosion of A by B, denoted $A \oplus B$, is defined as

$$A \ominus B = \{z|(\hat{B})_z \cap A \neq \varnothing\} \tag{7.3}$$

or

$$A \ominus B = \{z|[(\hat{B})_z \cap A] \subseteq A\} \tag{7.4}$$

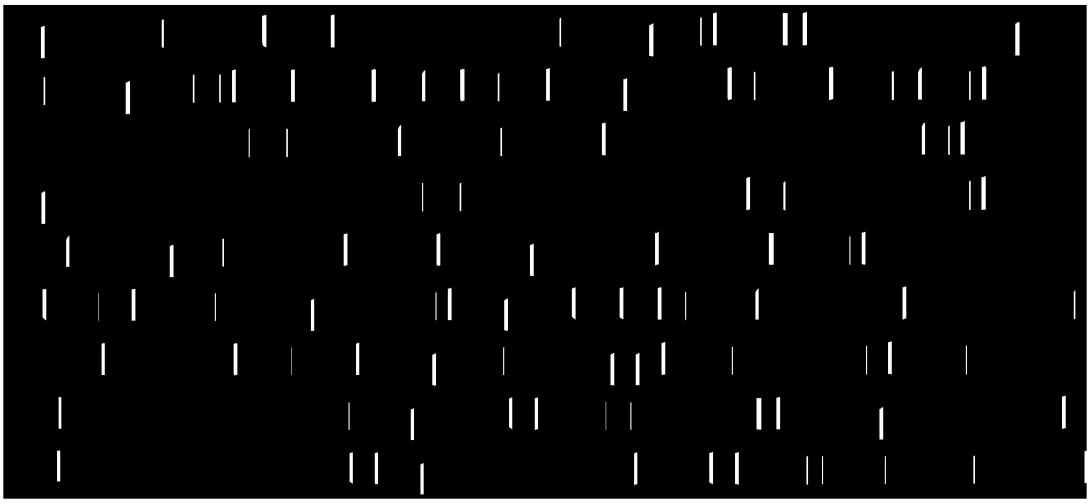

Figure 7.3: Erosion of Figure 7.2

7.3 Geodesic dilation and erosion

7.3.1 Geodesic dilation

Let F denote the marker image and G the mask image. It is assumed in this discussion that both are binary images and that $F \subseteq G$. The *geodesic dilation* of size 1 of the marker image with respect to the mask, denoted by $D_G^{(1)}(F)$, is defined as

$$D_G^{(1)}(F) = (F \oplus B) \cap G \tag{7.5}$$

The *geodesic dilation* of size n of F with respect to G is defined as

$$D_G^{(n)}(F) = D_G^{(1)}[D_G^{(n-1)}(F)] \tag{7.6}$$

7.3.2 Geodesic erosion

Similarly, the *geodesic erosion* of size 1 of marker F with respect to mask G is defined as

$$E_G^{(1)}(F) = (F \ominus B) \cup G \tag{7.7}$$

The *geodesic erosion* of size n of F with respect to G is defined as

$$E_G^{(n)}(F) = E_G^{(1)}[E_G^{(n-1)}(F)] \tag{7.8}$$

7.4 Opening by reconstruction

Opening by reconstruction restores *exactly* the shapes of the objects that remain after erosion.The opening by reconstruction of size n of an image F is defined as the reconstruction by dilation of F from the erosion of size n of F; that is,

$$O_R^{(n)}(F) = R_F^D[(F \ominus nB)] \tag{7.9}$$

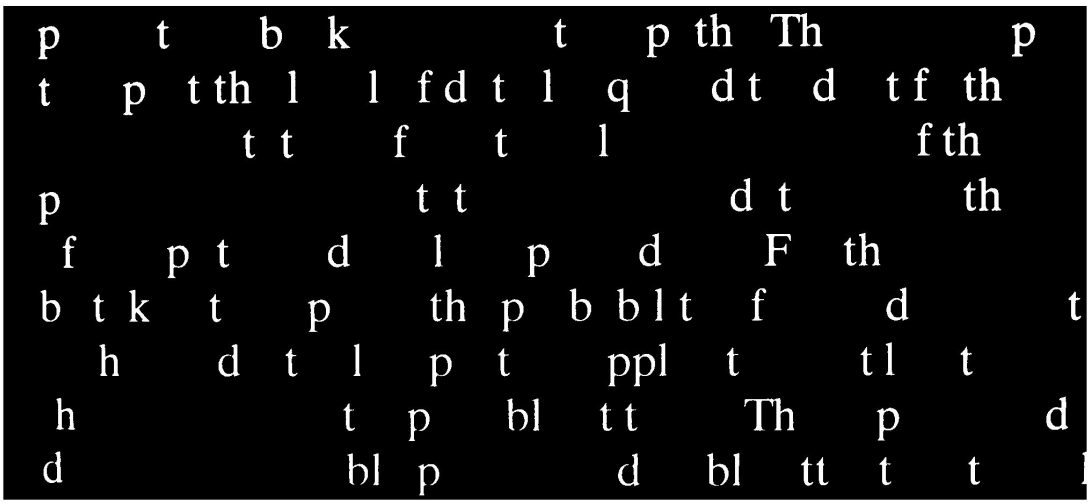

Figure 7.4: Opening by reconstruction of Figure 7.3

7.5 Filling holes

Let $I(x, y)$ denote a binary image and suppose that we form a marker image F that is 0 everywhere, except at the image border, where it is set to 1 - I; that is,

$$F(x,y) = \begin{cases} 1 - I(x,y), & if\ (x,y)\ is\ on\ the\ border\ of\ I \\ 0, & otherwise \end{cases} \tag{7.10}$$

Then

$$H = [R_{I^c}^D(F)]^c \tag{7.11}$$

is a binary image equal to I with all holes filled.

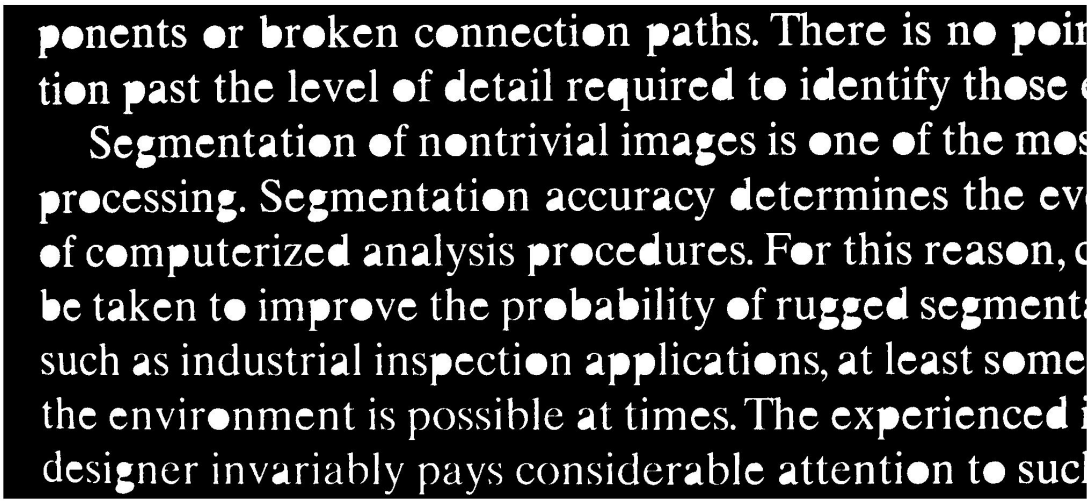

Figure 7.5: Filling holes of Figure 7.1

7.6 Border clearing

We use the original image as the mask and the following marker image:

$$F(x,y) = \begin{cases} I(x,y), & if\ (x,y)\ is\ on\ the\ border\ of\ I \\ 0, & otherwise \end{cases} \tag{7.12}$$

The border-Eclearing algorithm first computes the morphological reconstruction $R_I^D(F)$ (which simply extracts the objects touching the border) and then computes the difference

$$X = I - R_I^D(F) \tag{7.13}$$

to obtain an image, X, with no objects touching the border.

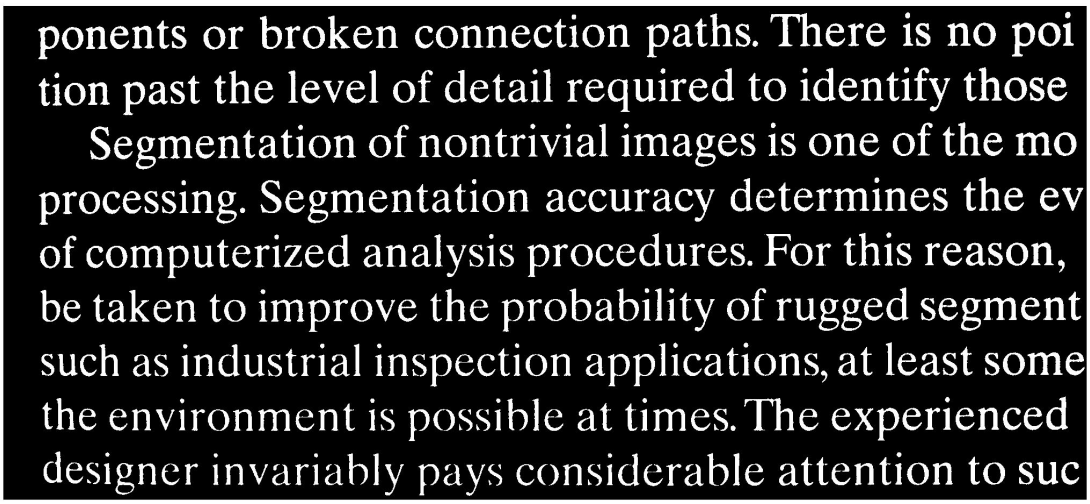

Figure 7.6: Border clearing of Figure 7.1

8.1 OverView

(a). Develop a program to implement the Roberts, Prewitt, Sobel, the Marr-Hildreth and the Canny edge detectors. Use the image 'building.tif' to test your detectors. (For technique details of Marr-Hildreth and Canny, please refer to pp.736-747 (3 rd edition, Gonzalez DIP, or pp.705-725 for the electronic textbook) or MH-Canny.pdf at the same address of the slides.)
(b). Develop a program to implement the Otsu' s method of thresholding segmentation, and compare the results with the global thresholding method using test image 'polymersomes.tif. (For technique details, please refer to pp.763-770 (3 rd edition, Gonzalez DIP, or pp.742-747 for the electronic textbook, or Otsu.pdf at the same ftp address of slides.)

8.2 Edge Detectors

8.2.1 Roberts

The Roberts operators are based on implementing the diagonal differences

$$g_x = \frac{\partial f}{\partial x} = z_9 - z_5 \tag{8.1}$$

$$g_y = \frac{\partial f}{\partial y} = z_8 - z_6 \tag{8.2}$$

Figure 8.1: Test Image

Figure 8.2: Roberts gx of Figure8.1

Figure 8.3: Roberts gy of Figure8.1

Figure 8.4: Roberts result of Figure8.1

8.2.2 Prewitt

The Prewitt operators:

$$g_x = \frac{\partial f}{\partial x} = (z_7 + z_8 + z_9) - (z_1 + z_2 + z_3) \tag{8.3}$$

$$g_y = \frac{\partial f}{\partial y} = (z_3 + z_6 + z_9) - (z_1 + z_4 + z_7) \tag{8.4}$$

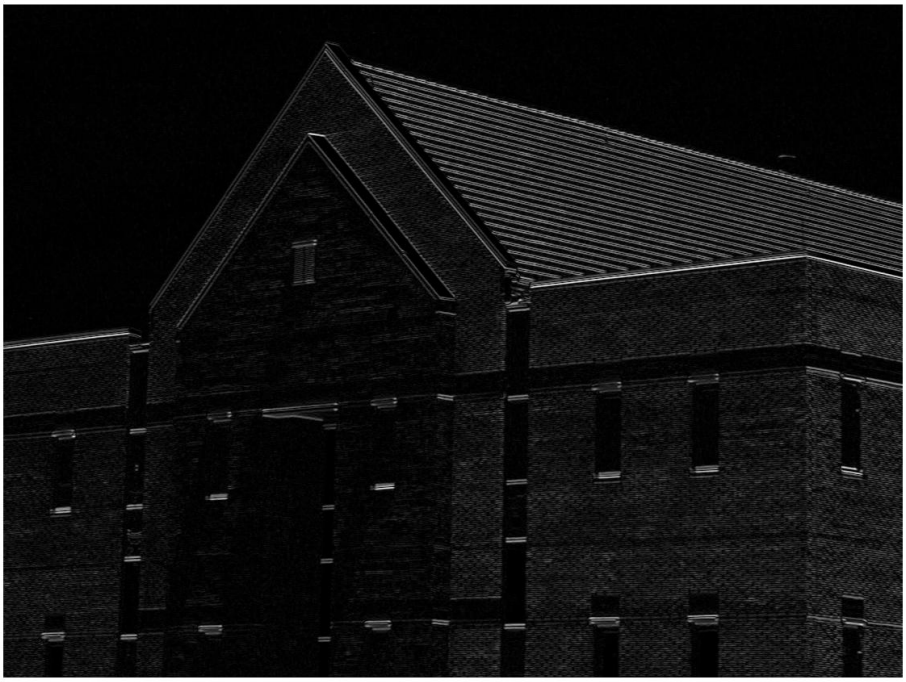

Figure 8.5: Prewitt gx of Figure8.1

Figure 8.6: Prewitt gy of Figure8.1

Figure 8.7: Prewitt result of Figure8.1

8.2.3 Sobel

The Sobel operators:

$$g_x = \frac{\partial f}{\partial x} = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3) \tag{8.5}$$

$$g_y = \frac{\partial f}{\partial y} = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7) \tag{8.6}$$

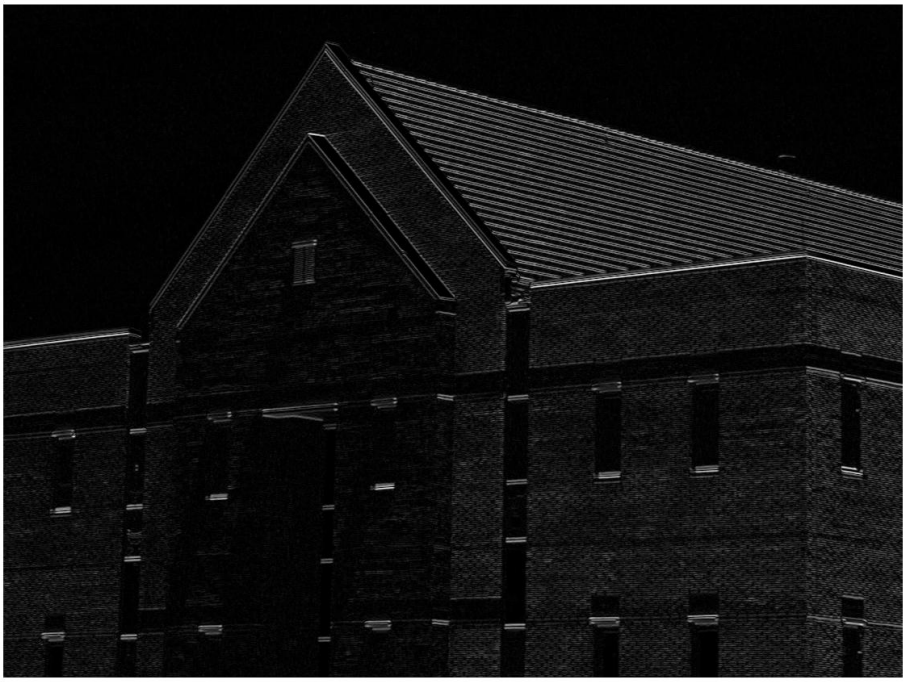

Figure 8.8: Sobel gx of Figure8.1

Figure 8.9: Sobel gy of Figure8.1

Figure 8.10: Sobel result of Figure8.1

8.2.4 Marr-Hildreth

- Calculate the Laplacian of Gaussian

$$LoG(x,y) = [\frac{x^2+y^2-2\sigma^2}{\sigma^4}]e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{8.7}$$

- Find the zero crossings of the image from last step
  - One approach for finding the zero crossings at any pixel, p, of the filtered image, $g(x,y)$, is based on using a 3 * 3 neighborhood centered at p. A zero crossing at p implies that the $signs$ of at least two of its opposing neighboring pixels must differ.There are four cases to test: left/right, up/down, and the two diagonals. If the values of $g(x,y)$ are being compared against a threshold (a common approach), then not only must the signs of opposing neighbors be different, but the absolute value of their numerical difference must also exceed the threshold before we can call p a zero-crossing pixel.

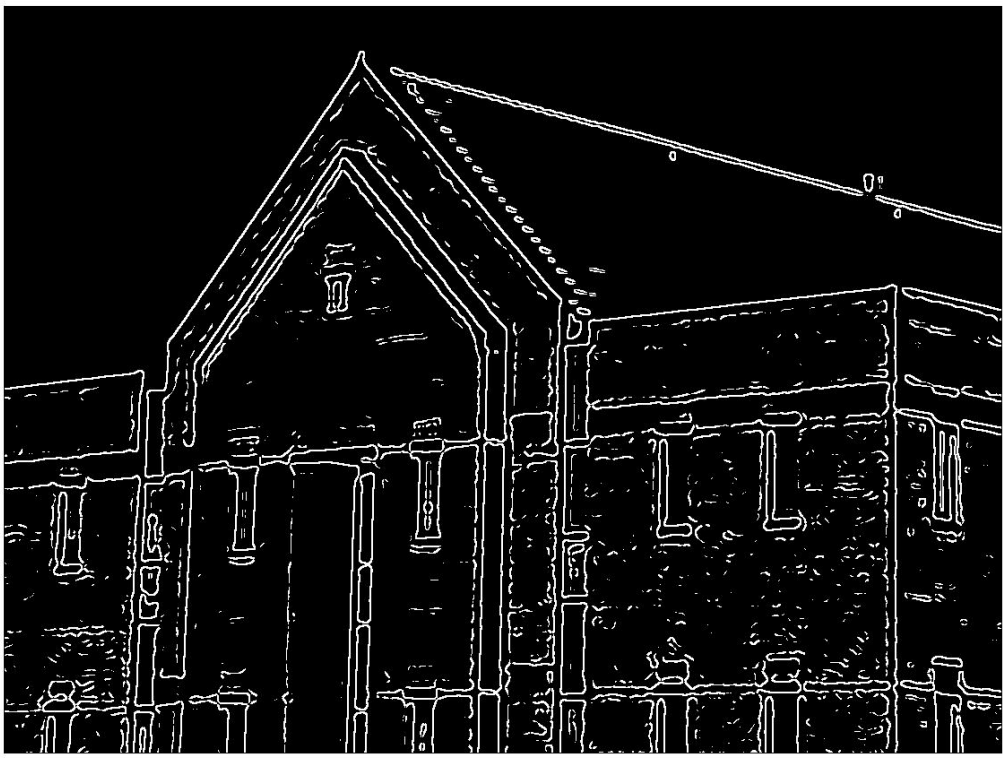

Figure 8.11: Marr-Hildreth result of Figure8.1

8.2.5 Canny

Let $f(x,y)$ denote the input image and $G(x,y)$ denote the Gaussian function:

$$G(x,y) = e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{8.8}$$

We form a smoothed image, $f_s(x,y)$, by convolving G and f:

$$f_s(x,y) = G(x,y) \bigstar f(x,y) \tag{8.9}$$

This operation is followed by computing the gradient magnitude and direction (angle)

$$M(x,y) = \sqrt{g_x^2 + g_y^2} \tag{8.10}$$

$$\alpha(x,y) = tan^{-1}[\frac{g_y}{g_x}] \tag{8.11}$$

with $g_x = \frac{\partial f_s}{\partial x}$ and $g_y = \frac{\partial f_s}{\partial y}$.

- Find the direction d_k that is closest to $a(x,y)$
- If the value of $M(x,y)$ is less than at least one of its two neighbors along d_k , let $g_N(x,y) = 0(suppression)$; otherwise, let $g_N(x,y) = M(x,y)$.
- Use double thresholding and connectivity analysis to detect and link edges.

Figure 8.12: Canny result of Figure8.1

8.3 Thresholding Segmentation

8.3.1 Global Thresholding

the segmented image, $g(x, y)$, is given by

$$g(x,y) = \begin{cases} 1, & if\ f(x,y) > T \\ 0, & if\ f(x,y) \leq T \end{cases} \tag{8.12}$$

- Select an initial estimate for the global threshold, T.
- Segment the image using T in Eq. (8.12).This will produce two groups of pixels: G_1 consisting of all pixels with intensity values $> T$, and G_2 consisting of pixels with values $\leq T$.
- Compute the average (mean) intensity values m_1 and m_2 for the pixels in G_1 and G_2 , respectively.
- Compute a new threshold value: $T = \frac{m_1+m_2}{2}$
- Repeat Steps 2 through 4 until the difference between values of T in successive iterations is smaller than a predefined parameter $\triangle T$

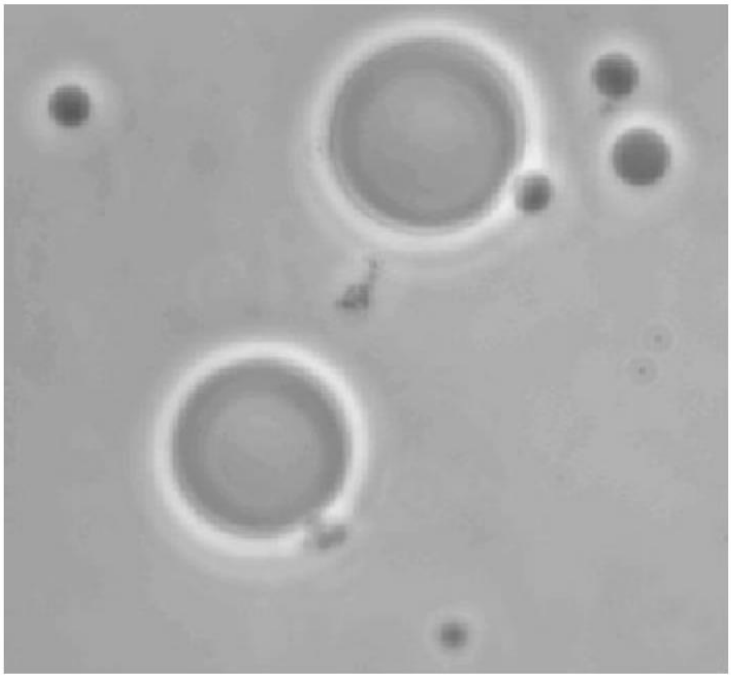

Figure 8.13: Test Image

Figure 8.14: Global Thresholding of Figure 8.13

8.3.2 Otsu

the probability, $P_1(k)$, that a pixel is assigned to (i.e., thresholded into) class C_1 is given by the cumulative sum

$$P_1(k) = \sum_{i=0}^{k} p_i \tag{8.13}$$

The cumulative mean (average intensity) up to level k is given by

$$m(k) = \sum_{i=0}^{k} ip_i \tag{8.14}$$

the average intensity of the entire image (i.e., the $global$ mean) is given by

$$m_G = \sum_{i=0}^{L-1} ip_i \tag{8.15}$$

we have the final results:

$$\sigma_B^2(k) = \frac{[m_G P_1(k) - m(k)]^2}{P_1(k)[1 - P_1(k)]} \tag{8.16}$$

Otsu' s algorithm may be summarized as follows:

- Compute the normalized histogram of the input image. Denote the components of the histogram by $p_i, i = 0, 1, 2, \cdots, L-1$.
- Compute the cumulative sums, $P_1(k)$, for $k = 0, 1, 2, \cdots, L-1$, using Eq. (8.13).
- Compute the cumulative means, $m(k)$, for $k = 0, 1, 2, \cdots, L-1$, using Eq. (8.14).
- Compute the global intensity mean, m_G , using (8.15).
- Compute the between-class variance, $\sigma_B^2(k)$, for $k = 0, 1, 2, \cdots, L-1$, using Eq. (8.16).
- Obtain the Otsu threshold, k^*, as the value of k for which $\sigma_B^2(k)$ is maxi-mum. If the maximum is not unique, obtain k^* by averaging the values of k corresponding to the various maxima detected.

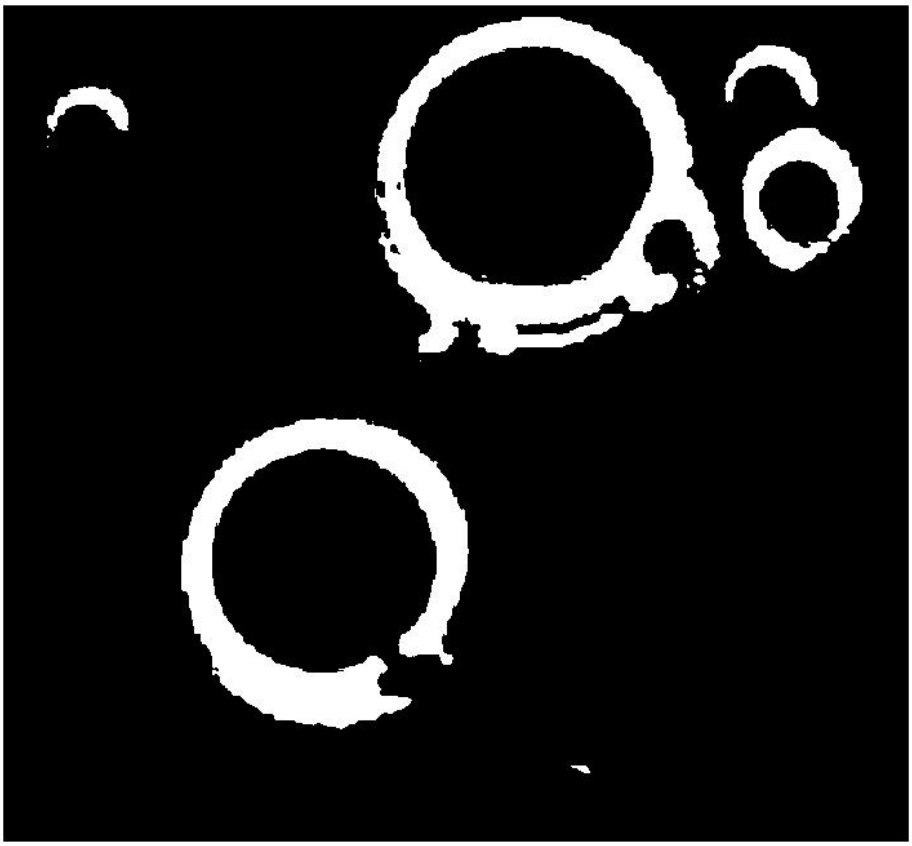

Figure 8.15: Otsu of Figure 8.13

A.1 Problem1

```
% Problem 1
% by Xue Fanyong
% Student ID:515030910443
% Histogram Equalizatio

%% Main Part
image1 = imread('Image Path/Fig1.jpg');
image2 = imread('Image Path/Fig2.jpg');

[histogram1,histogram_e1,transfer_f1,image_e1] =
histogram_equalization(image1);
[histogram2,histogram_e2,transfer_f2,image_e2] =
histogram_equalization(image2);

plot_data(image1,image_e1,histogram1,histogram_e1,transfer_f1);
plot_data(image2,image_e2,histogram2,histogram_e2,transfer_f2);

%% Functions Part

% get histogram of image
% image: get histogram of it
% histogram: the histogram of image
function histogram = get_histogram(image)
    histogram = zeros(256,1);
    [row,col]=size(image);
    for r = 1:row
        for c = 1:col
            gray = image(r,c);
            histogram(gray+1)=histogram(gray+1)+1;
        end
    end
end

% do the histogram_equalization for image
% image: do histogram_equalization for it
% histogram: original histogram; histogram_e:
% histogram after histogram
% equalizatio; transfer_f: transfer function;
% image_e: image after histogram
% equalizatio
function [histogram,histogram_e,transfer_f,image_e] =
histogram_equalization(image)
    [row,col]=size(image);
    transfer_f = zeros(256,1);
    histogram = get_histogram(image);
    transfer_f(1) = 256*histogram(1)/(row*col);

    for i = 2:256
        transfer_f(i) = transfer_f(i-1)+255*histogram(i)/(row*col);
```

```
    end
    transfer_f = round(transfer_f);

    image_e = image;
    for r = 1:row
        for c = 1:col
            image_e(r,c)=transfer_f(image(r,c)+1);
        end
    end
    histogram_e = get_histogram(image_e);
end

% plot data
% image:original image; image_e:
% image after histogram equalizatio;
% histogram: original histogram;
% histogram_e: histogram after histogram equalizatio;
% transfer_f: transfer function
function plot_data(image,image_e,histogram,histogram_e,transfer_f)
    figure();
    subplot(2,3,1);
    imshow(image);
    title(" Original Image");
    subplot(2,3,2);
    imshow(image_e);
    title(" Image(Histogram Equalization)");
    subplot(2,3,3);
    bar(histogram);
    title(" Histogram");
    subplot(2,3,4);
    bar(histogram_e);
    title(" Histogram(Equalization)");
    subplot(2,3,5);
    plot(transfer_f);
    title(" Transfer Funciton");
end
```

A.2 Problem 2

```
% Problem 2
% by Xue Fanyong
% Student ID:515030910443
% Combining spatial enhancement methods

%% Main Part
image = imread(' Image Path/skeleton_orig.tif');
[row,col] = size(image);
mask = [-1 -1 -1;-1 8 -1;-1 -1 -1];
mask = double(mask);
```

```
b_image = laplace_transformations(image,mask);
c_image = b_image+im2double(image);
d_image = sobel_gradient(image);
e_image = smooth(d_image);
f_image = im2double(e_image).*c_image;
g_image = abs(f_image)+im2double(image);
h_image = sqrt(g_image);
plot_data(image,b_image,c_image,d_image,
            e_image,f_image,g_image,h_image);

%% Function Part

% Laplace Transfromation for image using mask
% Input:
%   image:image you want to perform
%   mask:Laplace mask you want to use
% Output:
%   image_l:image after laplace transformation

function image_l = laplace_transformations(image,mask)
    [row,col] = size(image);
    mask = double(mask);
    %append image
    image_l = im2double(image);
    image = [zeros(row,2) image zeros(row,2)];
    image = [zeros(2,col+4);image;zeros(2,col+4)];
    image_append = im2double(image);

    for r = 1:row
        for c = 1:col
            image_l(r,c) = sum(sum(image_append(r:r+2,c:c+2).*mask));
        end
    end
end
%{
    sobel gradient for image
%}
function image_s = sobel_gradient(image)
    [row,col] = size(image);
    x_mask = [-1 -2 -1;0 0 0;1 2 1];
    y_mask = [-1 0 1;-2 0 2;-1 0 1];
    image_s = image;
    image = double(image);

    for r = 2:row-1
        for c = 2:col-1
            image_s(r,c) =
            abs(sum(sum(image(r-1:r+1,c-1:c+1).*x_mask)))+
            abs(sum(sum(image(r-1:r+1,c-1:c+1).*y_mask)));
        end
    end
```

```
end
%{
    smooth image using 5*5 mean filter
%}
function image_s = smooth(image)
    [row,col] = size(image);
    image_s = image;
    for r = 3:row-2
        for c = 3:col-2
            image_s(r,c) = mean(mean(image(r-2:r+2,c-2:c+2)));
        end
    end
end
%{
    plot data
%}
function plot_data(a,b,c,d,e,f,g,h)
    figure();

    subplot(241);
    imshow(a);
    title('(a) Oringinal Image');

    subplot(242);
    imshow(b,[]);
    title('(b) Laplacian of (a)');

    subplot(245);
    imshow(c,[]);
    title('(c) Sharpened image');

    subplot(246);
    imshow(d);
    title('(d) Sobel gradient');

    subplot(243);
    imshow(e);
    title('(e) Smoothed sobel image');

    subplot(244);
    imshow(f,[]);
    title('(f) Product of (c) and (e)');

    subplot(247);
    imshow(g,[]);
    title('(g) Sharpened image');

    subplot(248);
    imshow(h,[]);
    title('(h) Final result');
end
```

A.3 Problem 3

```
%{
    Problem 3
    by Fanyong Xue
    Student ID:515030910443
    Filtering in frequency domain

%}

%% Main Part
image = imread('Image Path/characters_test_pattern.tif');

ideal_low_plot_data(image);
ideal_high_plot_data(image);
butterworth_low_plot_data(image);
butterworth_high_plot_data(image);
gaussian_low_plot_data(image);
gaussian_high_plot_data(image);


%% Function Part

% Ideal
function ideal_high_plot_data(image)

    figure('name','Ideal High Pass');

    subplot(321);
    imshow(image);
    title('Original Image');

    subplot(322);
    imshow(IHPF(image,10),[]);
    title('Radius = 10');

    subplot(323);
    imshow(IHPF(image,30),[]);
    title('Radius = 30');

    subplot(324);
    imshow(IHPF(image,60),[]);
    title('Radius = 60');

    subplot(325);
    imshow(IHPF(image,160),[]);
    title('Radius = 160');

    subplot(326);
    imshow(IHPF(image,460),[]);
    title('Radius = 460');
```

```

end
function ideal_low_plot_data(image)

    figure('name','Ideal Low Pass');

    subplot(321);
    imshow(image);
    title('Original Image');

    subplot(322);
    imshow(ILPF(image,10),[]);
    title('Radius = 10');

    subplot(323);
    imshow(ILPF(image,30),[]);
    title('Radius = 30');

    subplot(324);
    imshow(ILPF(image,60),[]);
    title('Radius = 60');

    subplot(325);
    imshow(ILPF(image,160),[]);
    title('Radius = 160');

    subplot(326);
    imshow(ILPF(image,460),[]);
    title('Radius = 460');

end
function image_i = ILPF(image,radius)

    fliter = ILPF_fliter(image,radius);
    image_i = transfer(image,fliter);
    %{
    image_f = fft2(image,2*row,2*col);
    image_f = fftshift(image_f);
    %image_f = log(1+abs(image_f));

    %%%%%%%
    image_i = image_f.*fliter;

    image_i = ifftshift(image_i);
    image_i = ifft2(image_i);

    %image_i = abs(image_i);
    image_i = image_i(1:row,1:col);
    image_i = real(image_i);
    image_f = log(1+abs(image_f));
    %}
```

```
end
function image_i = IHPF(image,radius)
    fliter = 1-ILPF_fliter(image,radius);
    image_i = transfer(image,fliter);
end
function fliter = ILPF_fliter(image,radius)
    [row,col]=size(image);
    fliter = zeros(2*row,2*col);

    for r = 1:2*row
        for c = 1:2*col
            if sqrt((r-row)^2+(c-col)^2) <= radius
                fliter(r,c) = 1;
            end
        end
    end
end


% Butterworth
function butterworth_low_plot_data(image)
    figure('name','Butterworth Low Pass');

    subplot(321);
    imshow(image);
    title('Original Image');

    subplot(322);
    imshow(BLFP(image,2,10),[]);
    title('n=2,Radius = 10');

    subplot(323);
    imshow(BLFP(image,2,30),[]);
    title('n=2,Radius = 30');

    subplot(324);
    imshow(BLFP(image,2,60),[]);
    title('n=2,Radius = 60');

    subplot(325);
    imshow(BLFP(image,2,160),[]);
    title('n=2,Radius = 160');

    subplot(326);
    imshow(BLFP(image,2,460),[]);
    title('n=2,Radius = 460');

end
function butterworth_high_plot_data(image)
    figure('name','Butterworth High Pass');

```

```
    subplot(321);
    imshow(image);
    title(' Original Image');

    subplot(322);
    imshow(BHFP(image,2,10),[]);
    title(' n=2,Radius = 10');

    subplot(323);
    imshow(BHFP(image,2,30),[]);
    title(' n=2,Radius = 30');

    subplot(324);
    imshow(BHFP(image,2,60),[]);
    title(' n=2,Radius = 60');

    subplot(325);
    imshow(BHFP(image,2,160),[]);
    title(' n=2,Radius = 160');

    subplot(326);
    imshow(BHFP(image,2,460),[]);
    title(' n=2,Radius = 460');

end
function image_b = BLFP(image, n,radius)

    fliter = BLFP_fliter(image, n,radius);
    image_b = transfer(image,fliter);

end
function image_b = BHFP(image, n,radius)

    fliter = 1-BLFP_fliter(image, n,radius);
    image_b = transfer(image,fliter);

end
function fliter = BLFP_fliter(image, n,radius)
    [row,col]=size(image);
    fliter = zeros(2*row,2*col);

    for r = 1:2*row
        for c = 1:2*col
            fliter(r,c) = 1/(1+(sqrt((r-row)^2+
                        (c-col)^2)/radius)^(2*n));
        end
    end
end

% Gaussian
function gaussian_low_plot_data(image)
```

```
    figure('name','Gaussian Low Pass');

    subplot(321);
    imshow(image);
    title('Original Image');

    subplot(322);
    imshow(GLFP(image,10),[]);
    title('Radius = 10');

    subplot(323);
    imshow(GLFP(image,30),[]);
    title('Radius = 30');

    subplot(324);
    imshow(GLFP(image,60),[]);
    title('Radius = 60');

    subplot(325);
    imshow(GLFP(image,160),[]);
    title('Radius = 160');

    subplot(326);
    imshow(GLFP(image,460),[]);
    title('Radius = 460');
end
function gaussian_high_plot_data(image)
    figure('name','Gaussian High Pass');

    subplot(321);
    imshow(image);
    title('Original Image');

    subplot(322);
    imshow(GHFP(image,10),[]);
    title('Radius = 10');

    subplot(323);
    imshow(GHFP(image,30),[]);
    title('Radius = 30');

    subplot(324);
    imshow(GHFP(image,60),[]);
    title('Radius = 60');

    subplot(325);
    imshow(GHFP(image,160),[]);
    title('Radius = 160');

    subplot(326);
    imshow(GHFP(image,460),[]);
```

```
    title(' Radius = 460');
end
function image_g = GLFP(image,radius)
    fliter = GLFP_fliter(image,radius);
    image_g = transfer(image,fliter);
end
function image_g = GHFP(image,radius)
    fliter = 1-GLFP_fliter(image,radius);
    image_g = transfer(image,fliter);
end
function fliter = GLFP_fliter(image,radius)
    [row,col]=size(image);
    fliter = double(zeros(2*row,2*col));

    for r = 1:2*row
        for c = 2:2*col
            fliter(r,c) = exp(-1*(((r-row)^2+
                    (c-col)^2)/(2*radius^2)));
        end
    end
end

function image_t=transfer(image,fliter)
    [row,col]=size(image);
    image_f = fft2(image,2*row,2*col);
    image_f = fftshift(image_f);
    image_t = image_f.*fliter;
    image_t = ifftshift(image_t);
    image_t = ifft2(image_t);
    image_t = image_t(1:row,1:col);
    image_t = abs(image_t);
end
%{

function [ mfft2 ] = JCGuoFFT2( data )
    h = size(data, 1);
    w = size(data, 2);
    mfft2 = data;

    if power(2, log2(h)) ~= h || power(2, log2(w)) ~= w
        disp(' JCGuoFFT2 exit: h and w must be the power of 2!')
    else
        for i = 1 : h
            mfft2(i, :) = IterativeFFT(mfft2(i, :));
        end

        for j = 1 : w
            mfft2(:, j) = IterativeFFT(mfft2(:, j));
        end
    end
end
```

```
function image_s = shift_image(image)

    [row,col]=size(image);
    image_s = image;

    for r = 1:row
        for c = 1:col
            image_s(r,c) = image(r,c)*(-1)^(r+c);
        end
    end
end


function image_f = DFT(image,rows,cols)
    [row,col]=size(image);

    %pad image to rows*cols
    image = [image zeros(row,cols-col)];
    image = [image;zeros(rows-row,cols)];
    image = double(image);
    for i = 1:rows
        k = cols/2;
        M = round(log2(cols));
        for j = 1:cols-2
            if j<k
                t = image(i,k);
                image(i,k) = image(i,j);
                image(i,j) = t;
            end
            l = cols/2;
            while l<=k
                k = k-1;
                l = l/2;
            end
            k = k+1;
        end
        for m = 1:M
            la = 2^m;
            lb = la/2;
            for l = 1:lb
                r = (l-1)*2^(M-m);
                n = l-1;
                while n<rows-1
                    lc = n+lb;
                    t = image(lc,j)*exp(2*pi*r/rows);
                    image(i,lc) = image(i,n) - t;
                    image(i,n) = image(i,n) + t;
                    n = n+la;
                end
            end
```

```
        end
    end
    image_f = image;
end
function image_f=DFT(image,rows,cols)

end

function v = DFT_1(V)
    n = length(V);
    fft_m = BitReverseCopy(V);

    for r = 1:log2(n)
        m = power(2,r);
        wm = exp(- 2 * pi * i / m);

        for k = 0 : m : n - 1
            w = 1;
            for j = 0 : m / 2 - 1
                t = w * fft_m(k + j + m / 2 + 1);
                u = fft_m(k + j + 1);
                fft_m(k + j + 1) = u + t;
                fft_m(k + j + m / 2 + 1) = u - t;
                w = w * wm;
            end
        end
    end
end
%}
```

A.4 Problem 4

```
%{
    Problem 4
    by Fanyong Xue
    Student ID:515030910443
    Generating different types of noise and
    comparing different noise reduction methods
%}

%% Main Part
image = imread('Image Path/Fig0503.tif');
plot_data_noises(image);

circuit = imread('Image Path/Circuit.tif');
plot_data_noises(circuit);
plot_mean_filter(circuit);
plot_order_statistic_filter(circuit);

%% Function Part
```

```
% plot data by mean filters
function plot_mean_filter(image)
    figure('name','Mean Filters1');

    [row,col] = size(image);
    image = im2double(image);
    subplot(221);
    imshow(image);
    title('(a) X-ray image');

    n = uniform_noise(row,col,0,0.3);
    g = gaussian_noise(n,0,0.08);
    image_b = image+g;
    subplot(222);
    imshow(image_b);
    title('(b) Image corrupted by additive Gaussian noise');

    subplot(223);
    imshow(arithmetic_mean_filter(image_b,3,3));
    title('(c) Result of filtering with an arithmetic mean filter');

    subplot(224);
    imshow(geometric_mean_filter(image_b,3,3));
    title('(d) Result of filtering with a geometric mean filter');

    figure('name','Mean Filters2');

    subplot(221);
    image_a_ = impulse_noise(image,0.1,0,-1,0);
    imshow(image_a_);
    title('(a) Image corrupted by pepper noise');

    subplot(222);
    image_b_ = impulse_noise(image,0.1,0,1,0);
    imshow(image_b_);
    title('(b) Image corrupted by salt noise');


    subplot(223);
    imshow(contraharmonic_mean_filter(image_a_,1.5,3,3));
    title('(c) Result of filtering (a) with a contra-harmonic filter');

    subplot(224);
    imshow(contraharmonic_mean_filter(image_b_,-1.5,3,3));
    title('(c) Result of filtering (a) with a contra-harmonic filter');

    figure('name','Mean Filters3');

    subplot(121);
    imshow(contraharmonic_mean_filter(image_a_,-1.5,3,3));
    title('(c) Result of filtering (a) with a
```

```
                contra-harmonic filter(Q=-1.5)');

    subplot(122);
    imshow(contraharmonic_mean_filter(image_b_,1.5,3,3));
    title('(c) Result of filtering (a) with a
                contra-harmonic filter(Q=1.5)');
end
% plot data by order statistic filters
function plot_order_statistic_filter(image)
    figure('name','Order-Statistic Filters1');
    image = im2double(image);
    image_a = impulse_noise(image,0.1,0.1,-1,1);

    subplot(221);
    imshow(image_a);
    title('Image corrupted by salt-and-pepper noise');

    subplot(222);
    image_b = median_filter(image_a,3,3);
    imshow(image_b);
    title('(b) Result of one pass with a median filter');

    subplot(223);
    image_c = median_filter(image_b,3,3);
    imshow(image_c);
    title('(c) Result of processing (b) with the same filter');

    subplot(224);
    imshow(median_filter(image_c,3,3));
    title('(d) Result of processing (c) with the same filter');

    figure('name','Order-Statistic Filters2');

    image_a__ = impulse_noise(image,0.1,0,-1,0);
    subplot(121);
    imshow(max_filter(image_a__,3,3));
    title('(a) Result of filtering pepper noise with a max filter');

    image_b__ = impulse_noise(image,0.1,0,1,0);
    subplot(122);
    imshow(min_filter(image_b__,3,3));
    title('(a) Result of filtering salt noise with a min filter');

    figure('name','Order-Statistic Filters3');
    [row,col] = size(image);
    n = uniform_noise(row,col,0,0.3);
    image_a_ = image + n;
    subplot(321);
    imshow(image_a_);
    title('(a) Image corrupted by additive uniform noise');

```

```
    image_b_ = impulse_noise(image_a_,0.1,0.1,-1,1);
    subplot(322);
    imshow(image_b_);
    title('(b) Image corrupted by additive salt-and-pepper noise');

    subplot(323);
    imshow(arithmetic_mean_filter(image_b_,5,5));
    title('(c) Image (b) filtered with an arithmetic mean filter');

    subplot(324);
    imshow(geometric_mean_filter(image_b_,5,5));
    title('(c) Image (b) filtered with a geometric mean filter');

    subplot(325);
    imshow(median_filter(image_b_,5,5));
    title('(c) Image (b) filtered with a median filter');

    subplot(326);
    imshow(alpha_trimmed_mean_filter(image_b_,5,5,5));
    title('(c) Image (b) filtered with an alpha-trimmed mean filter');
end
% arithmetic mean filter with m*n mask
function image_ = arithmetic_mean_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
    %m and n should be odd numbers
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            image_(r,c) = mean(mean(image(r-m_:r+m_,c-n_:c+n_)));
        end
    end
end
% geometric mean filter with m*n mask
function image_ = geometric_mean_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            image_(r,c) = nthroot(prod(prod(
            image(r-m_:r+m_,c-n_:c+n_))),m*n);
        end
    end
end
% harmonic mean filter with m*n mask
function image_ = harmonic_mean_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
```

```
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            image_(r,c) = (m*n)/
            (sum(sum(1./image(
            r-m_:r+m_,c-n_:c+n_))));
        end
    end
end
% contraharmonic mean filter with m*n mask and its oder is q
function image_ = contraharmonic_mean_filter(image,q,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            image_(r,c) = (sum(sum(image(
            r-m_:r+m_,c-n_:c+n_).^(q+1))))/
            (sum(sum(image(
            r-m_:r+m_,c-n_:c+n_).^q)));
        end
    end
    image_ = real(image_);
end
% median filter with m*n mask
function image_ = median_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            image_(r,c) = median(median(image(r-m_:r+m_,c-n_:c+n_)));
        end
    end
end
% max filter with m*n mask
function image_ = max_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            temp = image(r-m_:r+m_,c-n_:c+n_);
            image_(r,c) = max(temp(:));
        end
    end
end
```

```
% min filter with m*n mask
function image_ = min_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            temp = image(r-m_:r+m_,c-n_:c+n_);
            image_(r,c) = min(temp(:));
        end
    end
end
% midpoint filter with m*n mask
function image_ = midpoint_filter(image,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            temp = image(r-m_:r+m_,c-n_:c+n_);
            image_(r,c) = (max(temp(:))+min(temp(:)))/2;
        end
    end
end
% alpha trimmed mean filter with m*n mask(deleta d pixels)
function image_ = alpha_trimmed_mean_filter(image,d,m,n)
    [row,col] = size(image);
    image_ = image;
    m_ = floor(m/2);
    n_ = floor(n/2);
    for r = ceil(m/2):row-m_
        for c = ceil(n/2):col-n_
            temp = image(r-m_:r+m_,c-n_:c+n_);
            temp_ = sort(temp(:));
            image_(r,c) = mean(temp_(floor(d/2):m*n-floor(d/2)));
        end
    end
end

% adding noises to image and plot them
function plot_data_noises(image)

    [row,col] = size(image);
    image = im2double(image);
    figure('name','Uniform Noise');
    n = uniform_noise(row,col,0,0.3);
    image_=image+n;
    subplot(121);
    imshow(image_,[]);
```

```
    subplot(122);
    bar(get_histogram(image_));

    figure('name','Gaussian Noise');
    g = gaussian_noise(n,0,0.08);
    image_ = image+g;
    subplot(121);
    imshow(image_,[]);
    subplot(122);
    bar(get_histogram(image_));

    figure('name','Rayleigh Noise');
    r = rayleigh_noise(n,-0.2,0.03);
    image_ = image+r;
    subplot(121);
    imshow(image_,[]);
    subplot(122);
    bar(get_histogram(image_));


    figure('name','Exponential Noise');
    e = exponential_noise(n,25);
    image_ = image+e;
    subplot(121);
    imshow(image_,[]);
    subplot(122);
    bar(get_histogram(image_));

    figure('name','Gamma Noise');
    ga = gamma_noise(n,25,3);
    image_ = image+ga;
    subplot(121);
    imshow(image_,[]);
    subplot(122);
    bar(get_histogram(image_));

    figure('name','Impulse Noise');
    image_ = impulse_noise(image,0.1,0.1,0.2,-0.2);
    subplot(121);
    imshow(image_,[]);
    subplot(122);
    bar(get_histogram(image_));
end
% row*col uniform noise from low~high
function n = uniform_noise(row,col,low,high)
    n = low + (high-low)*rand([row col]);
end
% normalizing uniform noise to 0~1
function n = normalized(uniform_noise)
    max_ = max(uniform_noise(:));
    min_ = min(uniform_noise(:));
```

```
    n = double(uniform_noise-min_);
    n = n/double(max_-min_);
end
% rayleigh noise
function n = rayleigh_noise(uniform_noise,a,b)
    uniform_noise_ = normalized(uniform_noise);
    n = a + sqrt(-b*log(1-uniform_noise_));
end
% exponential noise
function n = exponential_noise(uniform_noise,a)
    uniform_noise_ = normalized(uniform_noise);
    n = -1/a*log(1-uniform_noise_);
end
% impulse noise
function image_ = impulse_noise(image,pa,pb,a,b)
    [row,col]=size(image);
    uniform_noise_ = rand([row col]);
    image_ = image;
    for r = 1:row
        for c = 1:col
            if uniform_noise_(r,c)<pa
                image_(r,c) = image(r,c)+a;
            elseif uniform_noise_(r,c)>(1-pb)
                image_(r,c) = image(r,c)+b;
            end
        end
    end
end
% gamma noise
function n = gamma_noise(uniform_noise_,a,b)
    uniform_noise_ = normalized(uniform_noise_);
    n = -1/a*log(1-uniform_noise_);
    [row,col] = size(uniform_noise_);
    for i = 2:b
        uniform_noise__=uniform_noise(row,col,0,1);
        n = n-1/a*log(1-uniform_noise__);
    end

end
% gaussian noise
function n = gaussian_noise(uniform_noise,ex,sigma)
    [row,col] = size(uniform_noise);
    n_ = normalized(uniform_noise);
    n = n_;
    for r = 1:row
        if mod(col,2)==0
            for c = 1:2:col
                n(r,c) = sqrt(-2*log(n_(r,c)))*cos(2*pi*n_(r,c+1));
                n(r,c+1) = sqrt(-2*log(n_(r,c)))*sin(2*pi*n_(r,c+1));
            end
        else
```

```
            for c = 1:2:col-1
                n(r,c) = sqrt(-2*log(n_(r,c)))*cos(2*pi*n_(r,c+1));
                n(r,c+1) = sqrt(-2*log(n_(r,c)))*sin(2*pi*n_(r,c+1));
            end
            n(r,col) = sqrt(-2*log(n_(r,c)))*cos(2*pi*n_(r,1));
        end
    end
    n = n*double(sigma);
    n = n+ex;
end
% plot image' histogram (but add other 150 to
% display the negative value)
function histogram = get_histogram(image)
    [row,col]=size(image);
    histogram = zeros(500,1);%-150~350
    for r = 1:row
        for c = 1:col
            gray = int16(image(r,c) /0.004);
            if gray >349
                gray = 349;
            end
            if gray <-150
                gray = -150;
            end
            histogram(gray+1+150)=histogram(gray+1+150)+1;
        end
    end
end
```

A.5 Problem5

```
%{
    Problem 5
    by Fanyong Xue
        Student ID:515030910443
    Image restoration
%}
%% Main Part

clear all
image = imread('Image Path/book_cover.jpg');
image = im2double(image);

% motion blur
[row,col] = size(image);
image_f = fft2(image,row,col);
image_f2 = fftshift(image_f);
fliter = blurring_degradation(row,col,0.1,0.1,1);
image_t = image_f2.*fliter;
G = image_t;
```

```
image_t = ifftshift(image_t);
image_t = ifft2(image_t);
image_t = abs(image_t);
image_t = im2uint8(image_t);

% add noise
noise=gaussian_noise(row,col,0,25);
noise=int16(noise);
image_n = noise+int16(image_t);
image_n = uint8(image_n);
noise=uint8(noise);

% diaplsy
figure();
subplot(221);
imshow(image);
title('Original Image');
subplot(222);
imshow(image_t);
title('Blurred Image');
subplot(223);
imshow(noise);
title('Noise');
subplot(224);
imshow(image_n);
title('Blurred Image with Noise');

% restoration
% no noise
image_i = inverse_filter(G,fliter);
figure();
imshow(image_i);
title('Inverse Filter');

% with noise 650
N = fft2(im2double(noise));
N = fftshift(N);
G_ = G+N;
image_i2 = inverse_filter(G_,fliter);
image_w = wiener_filter(G_,fliter,0.03);
% display
figure();
subplot(121);
imshow(image_i2,[]);
title('Inverse Filter(650)');
subplot(122);
imshow(image_w);
title('Wiener Filter(650)');

%with noise 324
noise=gaussian_noise(row,col,0,18);
```

```
noise=uint8(noise);
N = fft2(im2double(noise));
N = fftshift(N);
G_ = G+N;

image_i2 = inverse_filter(G_,fliter);
image_w = wiener_filter(G_,fliter,0.01);

% display
figure();
subplot(121);
imshow(image_i2,[]);
title('Inverse Filter(324)');
subplot(122);
imshow(image_w);
title('Wiener Filter(324)');
%
%% Function Part
% blurring degradation
function h = blurring_degradation(row,col,a,b,T)

    h = double(zeros(row,col));
    for u  = 1:row
        for v = 1:col
            if u +v == col
                h(u,v)=1;
                continue;
            end
            h(u,v) = T/(pi*((u-row/2)*a+(v-col/2)*b))*
            sin(pi*((u-row/2)*a+(v-col/2)*b))*
            exp(-1i*pi*((u-row/2)*a+(v-col/2)*b));
        end
    end
end

% gaussian noise
function n = gaussian_noise(row,col,ex,sigma)
    n_ = rand([row col]);
    n = n_;
    for r = 1:row
        if mod(col,2)==0
            for c = 1:2:col
                n(r,c) = sqrt(-2*log(n_(r,c)))*cos(2*pi*n_(r,c+1));
                n(r,c+1) = sqrt(-2*log(n_(r,c)))*sin(2*pi*n_(r,c+1));
            end
        else
            for c = 1:2:col-1
                n(r,c) = sqrt(-2*log(n_(r,c)))*cos(2*pi*n_(r,c+1));
                n(r,c+1) = sqrt(-2*log(n_(r,c)))*sin(2*pi*n_(r,c+1));
            end
            n(r,col) = sqrt(-2*log(n_(r,c)))*cos(2*pi*n_(r,1));
```

```
            end
        end
        n = n*double(sigma);
        n = n+ex;
end
% inverse filter
function image_ = inverse_filter(g,h)
        image_ = g./h;
        image_ = ifftshift(image_);
        image_ = ifft2(image_);
        image_ = abs(image_);
end
% wiener filter
function image_ = wiener_filter(g,h,k)
        image_ = ((conj(h).*h)./((conj(h).*h)+k)).*g./h;
        image_ = ifftshift(image_);
        image_ = ifft2(image_);
        image_ = abs(image_);
end
```

A.6 Problem 6

```
%{
        Problem 6
        by Fanyong Xue
        Student ID:515030910443
        Geometric transform
%}

image = imread('Image Path/ray_trace_bottle.tif');
figure('name','rotate');
subplot(311);
imshow(image);
title('(a) Original Image');
subplot(312);
imshow(rotate(image,pi/6,'nearest neighbor'));
title('Rotate (a) by pi/6 using nearest neighbor');
subplot(313);
imshow(rotate(image,pi/6,'bilinear'));
title('Rotate (a) by pi/6 using bilinear');

figure('name','translate');
subplot(311);
imshow(image);
title('(a) Original Image');
subplot(312);
imshow(translate(image,500,500));
title('Translate (a) by x:500 and y:500');
subplot(313);
```

```
imshow(translate(image,-500,-500));
title(' Translate (a) by x:-500 and y:-500' );


figure(' name' ,' scale' );
subplot(221);
imshow(image);
title(' (a) Original Image' );
subplot(222);
image_b = scale(image,0.25,0.25,' bilinear' );
imshow(image_b);
title(' (b) Scale (a) to 0.25*0.25' );
subplot(223);
imshow(scale(image_b,2,2,' nearest neighbor' ));
title(' Scale (b) to 2*2 using nearest neighbor' );
subplot(224);
imshow(scale(image_b,2,2,' bilinear' ));
title(' Scale (b) to 2*2 using bilinear' );
%% Function Part

% rotate the point(v,w) angle degrees to point(x,y)
function [x,y]=rotate_axis(v,w,angle)
    x = round(v*cos(angle)-w*sin(angle));
    y = round(v*sin(angle)+w*cos(angle));
end
%{
    totate the image angle degrees with specified interpolation
    interpolation:' nearest neighbor' or ' bilinear'
%}
function image_ = rotate(image,angle,interpolation)
    [row,col] = size(image);
    x1 = 0;
    y1 = 0;
    [x2,y2] = rotate_axis(0,col-1,angle);
    [x3,y3] = rotate_axis(row-1,col-1,angle);
    [x4,y4] = rotate_axis(row-1,0,angle);
    y_r = max([y1 y2 y3 y4]) - min([y1 y2 y3 y4]);
    x_r = max([x1 x2 x3 x4]) - min([x1 x2 x3 x4]);
    image_ = -1*(ones(x_r+1,y_r+1));

    x_min = min([x1 x2 x3 x4]);
    y_min = min([y1 y2 y3 y4]);
    for x = 1:row
        for y = 1:col
            [x_,y_] = rotate_axis(x-1,y-1,angle);
            image_(x_-x_min+1,y_-y_min+1) = image(x,y);
        end
    end

    edge = zeros(x_r+1,2);
    for x = 1:x_r+1
```

```
        for y = 1:y_r+1
            if image_(x,y) == -1
                image_(x,y) = 0;
                continue;
            else
                break;
            end
        end
        edge(x,1) = y;
        for y = y_r+1:-1:1
            if image_(x,y) == -1
                image_(x,y) = 0;
            else
                break;
            end
        end
        edge(x,2) = y;
    end
    if strcmp(interpolation,'nearest neighbor')
        for x = 1:x_r+1
            for y = 1:y_r+1
                if image_(x,y) == -1
                    [x_ori,y_ori] = rotate_axis(x-1+x_min,
                        y-1+y_min,-1*angle);
                    v = find_nearest(image,x_ori+1,y_ori+1);
                    image_(x,y) = v(1);
                end
            end
        end
    elseif strcmp(interpolation,'bilinear')
        for x = 1:x_r+1
            for y = 1:y_r+1
                if image_(x,y) == -1
                    [x_ori,y_ori] = rotate_axis(x-1+x_min,
                        y-1+y_min,-1*angle);
                    v = find_nearest(image,x_ori+1,y_ori+1);
                    image_(x,y) = mean(v);
                end
            end
        end
    end

    image_ = uint8(image_);
end
% find the nearest point(up,down,left,right if have)
% which value is not -1
% and store them on v
function v = find_nearest(image,x,y)
    [row,col] = size(image);
    v = 0;
    found = 0;
```

```
    %up
    if x > 1 && image(x-1,y)~=-1
        v = image(x-1,y);
        found = 1;
    end
    %down
    if x<row && image(x+1,y)~=-1
        if found
            v = [v image(x+1,y)];
        else
            v = image(x+1,y);
            found =1;
        end

    end
    %left
    if y<col && image(x,y+1)~=-1
        if found
            v = [v image(x,y+1)];
        else
            v = image(x,y+1);
            found =1;
        end
    end
    %right
    if y>1 && image(x,y-1)~=-1
        v = [v image(x,y-1)];
        if found
            v = [v image(x,y-1)];
        else
            v = image(x,y-1);
        end
    end
end

% translate the image by tx in x dimension and ty in y dimension

function image_ = translate(image,tx,ty)
    [row,col] = size(image);

    if tx>0
        image_ = [zeros(row,tx) image];
    else
        image_ = [image zeros(row,-1*tx)];
    end

    if ty>0
        image_ = [zeros(ty,col+abs(tx));image_];
    else
        image_ = [image_;zeros(abs(ty),col+abs(tx))];
    end
```

```
end
%{
    scale the image by cx in x dimension and cy in y dimension
    with specified interpolation
    interpolation:' nearest neighbor' or ' bilinear'
%}
function image_ = scale(image,cx,cy,interpolation)
    [row,col] = size(image);
    row_ = ceil(row*cx);
    col_ = ceil(col*cy);
    image_ = -1*ones(row_,col_);

    for x = 1:row
        for y = 1:col
            image_(ceil(x*cx),ceil(y*cy)) = image(x,y);
        end
    end
    if cx>1 || cy>1
        if strcmp(interpolation,' nearest neighbor' )
            for x = 1:row_
                for y = 1:col_
                    if image_(x,y)==-1
                        x_ori = ceil(x/cx);
                        y_ori = ceil(y/cy);
                        v = find_nearest(image,x_ori,y_ori);
                        image_(x,y) = v(1);
                    end
                end
            end
        elseif strcmp(interpolation,' bilinear' )
            for x = 1:row_
                for y = 1:col_
                    if image_(x,y)==-1
                        x_ori = ceil(x/cx);
                        y_ori = ceil(y/cy);
                        v = find_nearest(image,x_ori,y_ori);
                        image_(x,y) = mean(v);
                    end
                end
            end
        end
    end
    image_ = uint8(image_);
end
```

A.7 Problem 8

```
%{
    Problem 8
```

```
    by Fanyong Xue
    Student ID:515030910443
    Morpholigical Processing
%}

%% Main Part
image = imread('Image Path/Fig0929(a)(text_image).tif');
figure();
imshow(image);

b=erode(image,51,1);
figure();
imshow(b);
c = dilate(b,51,1);
figure();
imshow(c);

d = rd(b,image,8);
figure();
imshow(d);

e=filling_holes(image);
figure();
imshow(e);

f = border_clearing(image);
figure();
imshow(f);

%% Function Part
function image_ = dilate(image,mask_size_x,mask_size_y)
    [row,col] = size(image);
    %{
    image_ = zeros(row,col);

    image = [zeros(row,floor(mask_size_y/2)) image
              zeros(row,floor(mask_size_y/2))];
    image = [zeros(floor(mask_size_x/2),col+mask_size_y-1);image;
        zeros(floor(mask_size_x/2),col+mask_size_y-1)];

    for r = 1:row
        for c = 1:col
            image_(r,c) = logical(max(max(image(r:r+mask_size_x-1,
                                c:c+mask_size_y-1))));
        end
    end
    %}
    image_ = zeros(row+mask_size_x-1,col+mask_size_y-1);%append
    for r = 1:row
        for c = 1:col
            if image(r,c)
```

```
                    image_(r:r+mask_size_x-1,c:c+mask_size_y-1) =
                                ones(mask_size_x,mask_size_y);
                end
            end
        end
        image_ = logical(image_(ceil(mask_size_x/2):
                row+floor(mask_size_x/2),
                ceil(mask_size_y/2):
                col+floor(mask_size_y/2)));
end

function image_ = erode(image,mask_size_x,mask_size_y)
    [row,col] = size(image);
    image_ = zeros(row,col);

    image = [ones(row,floor(mask_size_y/2))
            image ones(row,floor(mask_size_y/2))];
    image = [ones(floor(mask_size_x/2),col+mask_size_y-1);image;
           ones(floor(mask_size_x/2),col+mask_size_y-1)];

    for r = 1:row
        for c = 1:col
            image_(r,c) = logical(min(min(image(r:r+mask_size_x-1,
                        c:c+mask_size_y-1))));
        end
    end
end

function image_ = rd(F,G,f)
    figure(f);
    pre_DGF = logical(and_image(dilate(F,3,3),G));
    DGF = logical(and_image(dilate(pre_DGF,3,3),G));
    while image_different(pre_DGF,DGF)
        pre_DGF = DGF;
        DGF = logical(and_image(dilate(pre_DGF,3,3),G));
        imshow(DGF);
    end
    image_ = DGF;
    close(figure(f));
end

function image_ = re(F,G)
    pre_DGF = logical(or_image(erode(F,3,3),G));
    DGF = logical(or_image(erode(pre_DGF,3,3),G));
    while image_different(pre_DGF,DGF)
        pre_DGF = DGF;
        DGF = logical(and_image(erode(pre_DGF,3,3),G));
    end
    image_ = DGF;
end
```

```
function image_ = and_image(image1,image2)
    image_ = image1&image2;
end
function image_ = or_image(image1,image2)
    image_ = image1|image2;
end
function v = image_different(image1,image2)
    v = sum(sum(image1-image2));
end
function image_ = filling_holes(image)
    image_c = ~image;
    [row,col] = size(image);
    image_ = ones(row,col) - image;
    image_(2:row-1,2:col-1) = zeros(row-2,col-2);
    image_ = logical(image_);
    image_h = rd(image_,image_c,9);
    image_ = ~image_h;

end
function image_ = border_clearing(image)
    [row,col] = size(image);
    image_f = image;
    image_f(2:row-1,2:col-1) = zeros(row-2,col-2);
    image_f = logical(image_f);

    image_ = image - rd(image_f,image,7);

end
```

A.8 Problem9

```
%{
    Problem 9
    by Fanyong Xue
    Student ID:515030910443
    Image segmentation
%}
%% Main Part
clear all
image = imread('Image Path/building.tif');
image2 = imread('Image Path/polymersomes.tif');

Sobel_x = double([-1 -2 -1;0 0 0;1 2 1]);
Sobel_y = double([-1 0 1;-2 0 2;-1 0 1]);
Prewitt_x = double([-1 -1 -1;0 0 0;1 1 1]);
Prewitt_y = double([-1 0 1;-1 0 1;-1 0 1]);
Roberts_x = double([-1 0;0 1]);
Roberts_y = double([0 -1;1 0]);

```

```
figure('name','Sobel');
[k1,k2]=detectors(image,Sobel_x,Sobel_y);
subplot(221);
imshow(image);
subplot(222);
imshow(k1,[]);
subplot(223);
imshow(k2,[]);
subplot(224);
imshow(k1+k2,[]);

figure('name','Prewitt');
[k1_,k2_]=detectors(image,Prewitt_x,Prewitt_y);
subplot(221);
imshow(image);
subplot(222);
imshow(k1_,[]);
subplot(223);
imshow(k2_,[]);
subplot(224);
imshow(k1_+k2_,[]);

figure('name','Roberts');
[k1__,k2__]=detectors(image,Roberts_x,Roberts_y);
subplot(221);
imshow(image);
subplot(222);
imshow(k1__,[]);
subplot(223);
imshow(k2__,[]);
subplot(224);
imshow(k1__+k2__,[]);

figure('name','Marr Hildreth');
[image_m1,image_m2]=Marr_Hildreth(image,4,25);
subplot(121);
imshow(image_m1);
subplot(122);
imshow(image_m2);

figure('name','Canny');
imshow(Canny(image));
figure('name','Basic Global Thresholding');
imshow(Basic_Global_Thresholding(image2,0));
figure('name','Otsu');
imshow(Otsu(image2));


%% Function Part

function [image_x,image_y] = detectors(image,mask_x,mask_y)
```

```
    image = double(image);
    image_x = image;
    image_y = image;
    [row,col] = size(image);
    [m_x,m_y] = size(mask_x);
    if m_x <= 2 && m_y <=2
        mask_x = [zeros(m_x,1) mask_x];
        mask_x = [zeros(1,1+m_y);mask_x];
        mask_y = [zeros(m_x,1) mask_y];
        mask_y = [zeros(1,1+m_y);mask_y];
    end
    [m_x,m_y] = size(mask_x);
    append_x = floor(m_x/2);
    append_y = floor(m_y/2);
    %image append
    image = [ones(append_y,1)*image(1 ,:);image;
        ones(append_y,1)*image(end,:)];
    image = [image(:,1)*ones(1,append_x) image
        image(:,end)*ones(1,append_x)];

    for r = 1:row
        for c = 1:col
            image_x(r,c) = abs(sum(sum(
            image(r:r+m_x-1,c:c+m_y-1).*mask_x)));
        end
    end

    for r = 1:row
        for c = 1:col
            image_y(r,c) = abs(sum(sum(
            image(r:r+m_x-1,c:c+m_y-1).*mask_y)));
        end
    end

end

function [image__,image_] = Marr_Hildreth(image,sigma,n)
    g = zeros(n);
    image = double(image);
    image_=image;
    [row,col] = size(image);
    image__= zeros(row,col);
    for r = -1*floor(n/2):floor(n/2)
        for c = -1*floor(n/2):floor(n/2)
            g(r+floor(n/2)+1,c+floor(n/2)+1) =
              ((r*r+c*c-2*sigma*sigma)/(sigma^4))*
                exp(-1*(r*r+c*c)/(2*sigma*sigma));
        end
    end

```

```
    image = [ones(floor(n/2),1)*image(1,:);
        image;ones(floor(n/2),1)*image(end,:)];
    image = [image(:,1)*ones(1,floor(n/2)) image
        image(:,end)*ones(1,floor(n/2))];

    for r = 1:row
        for c = 1:col
            image_(r,c) = sum(sum(image(r:r+n-1,c:c+n-1).*g));
        end
    end
    t = 0.04*max(max(image_));
    %zero

    for r = 2:row-1

        for c = 2:col-1
            zeros_ = 0;
            if po_ne(image_(r+1,c))+po_ne(image_(r-1,c))==0 &&
             abs(image_(r+1,c)-image_(r-1,c))>=t
                zeros_ = zeros_+1;
            end
            if po_ne(image_(r,c+1))+po_ne(image_(r,c-1))==0 &&
             abs(image_(r,c+1)-image_(r,c-1))>=t
                zeros_ = zeros_+1;
            end
            if po_ne(image_(r+1,c+1))+po_ne(image_(r-1,c-1))==0 &&
             abs(image_(r+1,c+1)-image_(r-1,c-1))>=t
                zeros_ = zeros_+1;
            end
            if po_ne(image_(r+1,c-1))+po_ne(image_(r-1,c+1))==0 &&
             abs(image_(r+1,c-1)-image_(r-1,c+1))>=t
                zeros_ = zeros_+1;
            end
            if zeros_>=1
                image__(r,c)=255;
            else
                image__(r,c) = 0;
            end

        end
    end
    image_ = im2double(image_);
end

function v_ = po_ne(v)
    if v > 0
        v_ = 1;
    elseif v<0
        v_ = -1;
    else
        v_ =2;
```

```
    end
end

function image_res = Canny(image)
    n = 25;
    sigma=4;
    g = zeros(n);
    image = double(image);
    image_=image;
    [row,col] = size(image);
    for r = -1*floor(n/2):floor(n/2)
        for c = -1*floor(n/2):floor(n/2)
            g(r+floor(n/2)+1,c+floor(n/2)+1) =
                exp(-1*(r*r+c*c)/(2*sigma*sigma));
        end
    end
    image = [ones(floor(n/2),1)*image(1,:);
          image;ones(floor(n/2),1)*image(end,:)];
    image = [image(:,1)*ones(1,floor(n/2))
          image image(:,end)*ones(1,floor(n/2))];

    for r = 1:row
        for c = 1:col
            image_(r,c) = sum(sum(image(r:r+n-1,c:c+n-1).*g));
        end
    end
    Roberts_x = double([-1 0;0 1]);
    Roberts_y = double([0 -1;1 0]);
    [gx,gy] = detectors(image_,Roberts_x,Roberts_y);
    M = sqrt(gx.^2+gy.^2);
    alpha = atan(gy./gx);
    gn = M;
    for r = 2:row-1
        for c = 2:col-1
            p = part(alpha(r,c));
            if p == 1
                nei1 = M(r-1,c);
                nei2 = M(r+1,c);
            elseif p==2
                nei1 = M(r-1,c-1);
                nei2 = M(r+1,c+1);
            elseif p==3
                nei1 = M(r,c+1);
                nei2 = M(r,c-1);
            else
                nei1 = M(r-1,c+1);
                nei2 = M(r+1,c-1);
            end
            if M(r,c)<nei1 || M(r,c)<nei2
                gn(r,c)=0;
            else
```

```
                    gn(r,c)=M(r,c);
                end
            end
        end
        %gn=uint8(gn);
        tl=185;
        th=370;
        gh=gn*0;
        gl=gn*0;
        for r = 1:row
            for c = 1:col
                if gn(r,c)>=th
                    gh(r,c)=gn(r,c);
                    gl(r,c)=gn(r,c);
                elseif gn(r,c)>=tl
                    gl(r,c)=gn(r,c);
                end
            end
        end
        image_res = zeros(row,col);
        go = logical(zeros(row,col));
        for r = 1:row
            for c = 1:col
                if gh(r,c)>0 && image_res(r,c)==0
                    image_res(r,c) = gh(r,c);
                    [image_res,go]=go_through(image_res,go,gl,r,c,row,col);

                end
            end
        end

end

function [image_,go] = go_through(image_,go,image,x,y,row,col)
        if x>1&&image(x-1,y)>0&&~go(x-1,y)
            image_(x-1,y)=image(x-1,y);
            go(x-1,y)=1;
            [image_,go]=go_through(image_,go,image,x-1,y,row,col);
        end
        if y>1&&image(x,y-1)>0&&~go(x,y-1)
            image_(x,y-1)=image(x,y-1);
            go(x,y-1)=1;
            [image_,go]=go_through(image_,go,image,x,y-1,row,col);

        end

        if x<row&&image(x+1,y)>0&&~go(x+1,y)
            image_(x+1,y)=image(x+1,y);
            go(x+1,y)=1;
            [image_,go]=go_through(image_,go,image,x+1,y,row,col);

```

```
    end
    if y<col&&image(x,y+1)>0&&~go(x,y+1)
        image_(x,y+1)=image(x,y+1);
        go(x,y+1)=1;
        [image_,go]=go_through(image_,go,image,x,y+1,row,col);

    end
    if x>1&&y>1&&image(x-1,y-1)>0&&~go(x-1,y-1)
        image_(x-1,y-1)=image(x-1,y-1);
        go(x-1,y-1)=1;
        [image_,go]=go_through(image_,go,image,x-1,y-1,row,col);

    end
    if x<row&&y<col&&image(x+1,y+1)>0&&~go(x+1,y+1)
        image_(x+1,y+1)=image(x+1,y+1);
        go(x+1,y+1)=1;
        [image_,go]=go_through(image_,go,image,x+1,y+1,row,col);

    end
    if x>1&&y<col&&image(x-1,y+1)>0&&~go(x-1,y+1)
        image_(x-1,y+1)=image(x-1,y+1);
        go(x-1,y+1)=1;
        [image_,go]=go_through(image_,go,image,x-1,y+1,row,col);

    end
    if x<row&&y>1&&image(x+1,y-1)>0&&~go(x+1,y-1)
        image_(x+1,y-1)=image(x+1,y-1);
        go(x+1,y-1)=1;
        [image_,go]=go_through(image_,go,image,x+1,y-1,row,col);

    end
end
function v = part(angle)
    if (-pi/2 <= angle && angle <= -3*pi/8)||
        (pi/2 >= angle && angle >= 3*pi/8)
        v= 1;
    elseif -3*pi/8<= angle && angle <=-1*pi/8
        v=2;
    elseif -1*pi/8<=angle && angle<=1*pi/8
        v = 3;
    else
        v=4;
    end
end

function image_ = Basic_Global_Thresholding(image,delta)
    [row,col] = size(image);
    g1=zeros(row,col);
    g2=zeros(row,col);
    m = mean(mean(image));
    prevm = 0;
```

```
    while abs(m-prevm)>delta
        for r = 1:row
            for c = 1:col
                if image(r,c)>m
                    g1(r,c) = image(r,c);
                else
                    g2(r,c) = image(r,c);
                end
            end
        end
        prevm = m;
        m = (mean(mean(g1))+mean(mean(g2)))/2;
    end
    image_ = zeros(row,col);
    for r = 1:row
        for c = 1:col
            if image(r,c)>m
                image_(r,c)=image(r,c);
            end
        end
    end
end
function image_=Otsu(image)

    [row,col] = size(image);

    image_ = zeros(row,col);
    p = get_histogram(image);
    p = double(p);
    p = p./(row*col);
    P1 = zeros(256,1);
    P1(1) = p(1);
    for k=2:256
        P1(k) = P1(k-1)+p(k);
    end

    m = zeros(256,1);
    m(1)=0;

    for k=2:256
        m(k) = m(k-1)+(k-1)*p(k);
    end
    mg = m(256);
    max_v = 0;
    max_k=zeros(256,1);
    max_k(1) = 1;
    num_k=1;
    for k = 1:256
        sigma = (mg*P1(k)-m(k))^2/(P1(k)*(1-P1(k)));
        if sigma > max_v
            max_k(1)=k;
```

```
                num_k=1;
                max_v = sigma;
            elseif sigma == max_v
                num_k = num_k+1;
                max_k(num_k) = k;
            end
        end
        max_k_ = mean(max_k(1:num_k));
        for r = 1:row
            for c = 1:col
                if image(r,c)>max_k_
                    image_(r,c)=image(r,c);
                end
            end
        end
end

function histogram = get_histogram(image)
    histogram = zeros(256,1);
    [row,col]=size(image);
    for r = 1:row
        for c = 1:col
            gray = image(r,c);
            histogram(gray+1)=histogram(gray+1)+1;
        end
    end
end
```