DIP Report

呂翊愷

Assignment #1 - warm up

- Please convert the given color image I_1 as shown in Fig.1 to a gray-level one. Please also perform diagonal flipping on it and output the result as B.
- color image to gray-level image :

  Gray = R * 0.299 + G * 0.587 + B * 0.114

- diagonal flipping :

  flipImg(i, j) = img(j, i);

Assignment #1 - warm up

- Please convert the given color image I_1 as shown in Fig.1 to a gray-level one. Please also perform diagonal flipping on it and output the result as B.

image I1

image B

Assignment #1 - problem 1(a)

- (a) Decrease the brightness of I_2 by dividing the intensity values by 3 and output the image as D.

- D(i, j) = img(i, j) / 3;

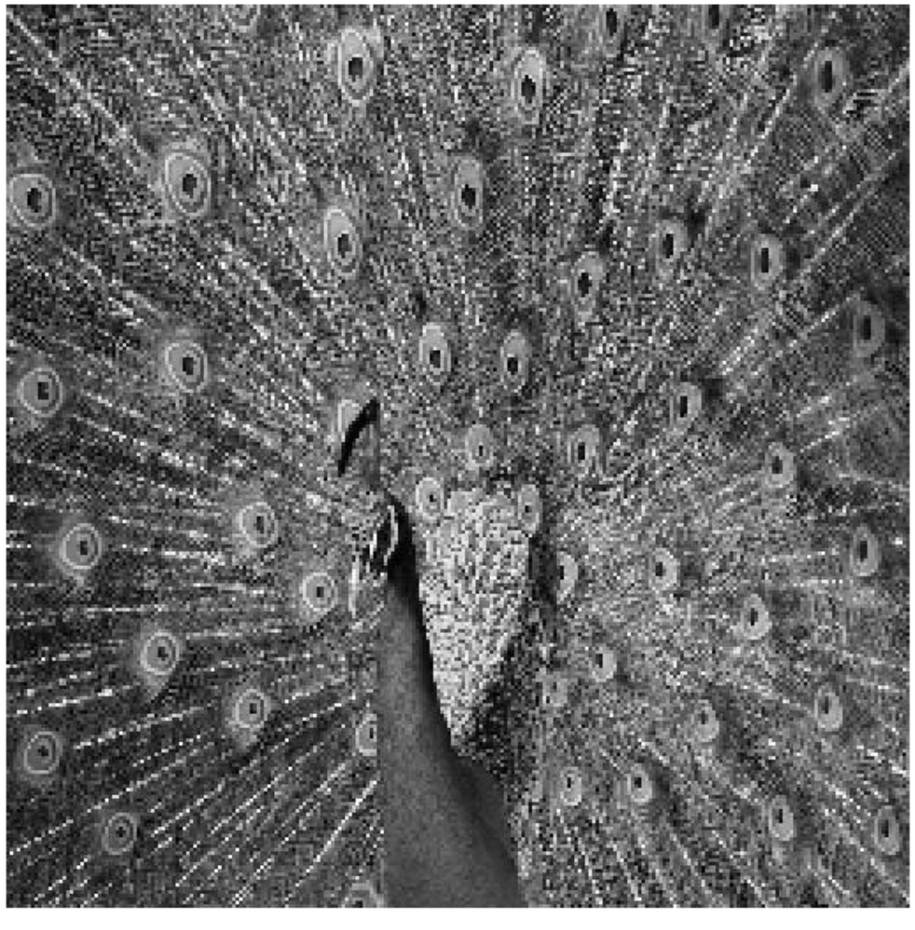
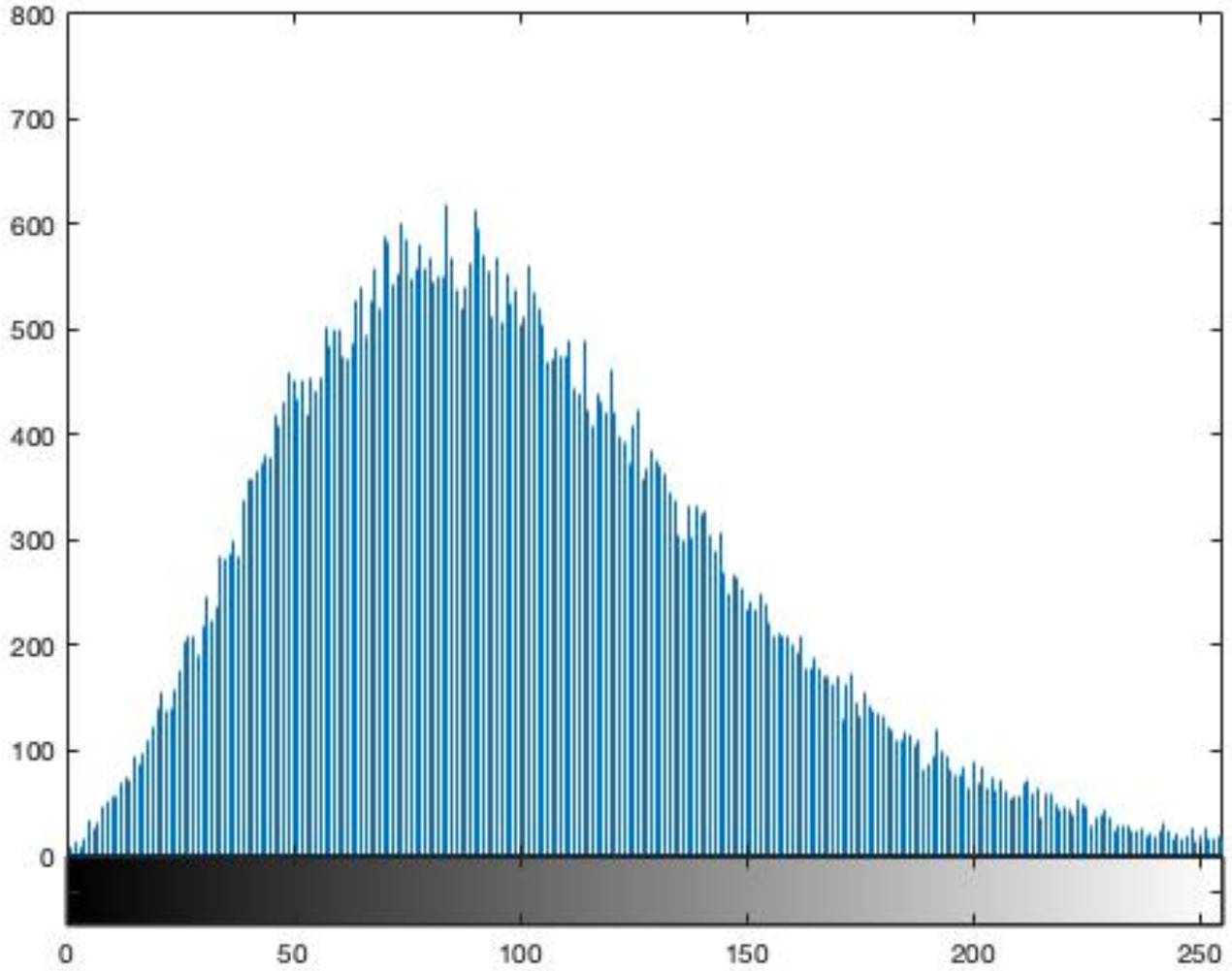


image I2

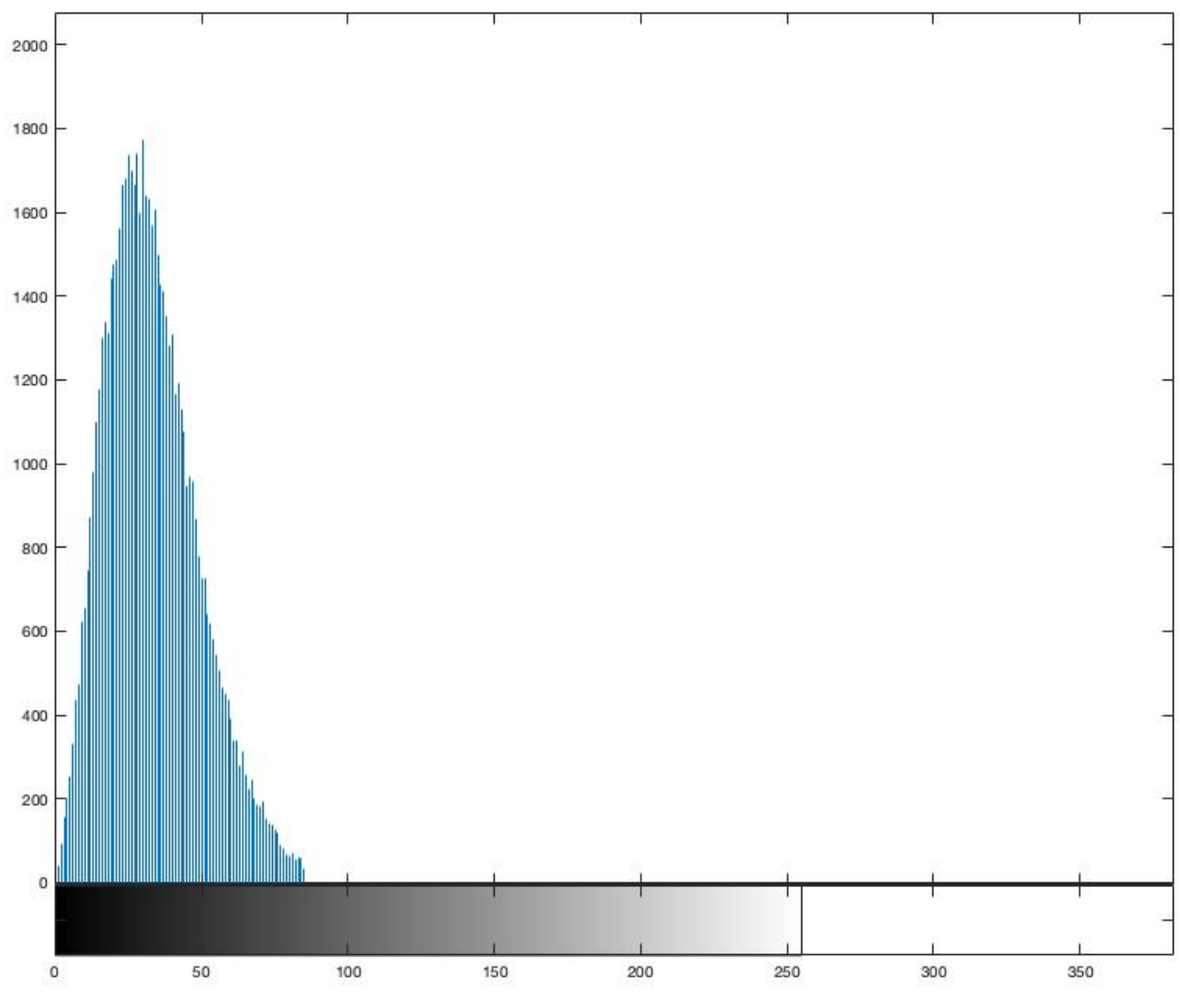
image D

Assignment #1 - problem 1(b)

- (b) Plot the histograms of I_2 and D. What can you observe from these two histograms?



histogram of I2



histogram of D

Assignment #1 - problem 1(c)

- (c) Perform histogram equalization on D and output the result as H.

① Histogram equalization:

I. 統計原圖的不同灰階值的histogram

II. 計算概率累積分佈函數cdf

$$C(r_k) = \sum_{i=0}^{k} P(r_i) = \sum_{i=0}^{k} \frac{n_i}{n}$$

III. 利用transfer function對cdf進行equalization

$$\mathrm{H}(v) = (int)\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L-1)\right)$$

IV. 利用新的cdf值對原圖進行equalization

Assignment #1 - problem 1(c)

- (c) Perform histogram equalization on D and output the result as H.

image D

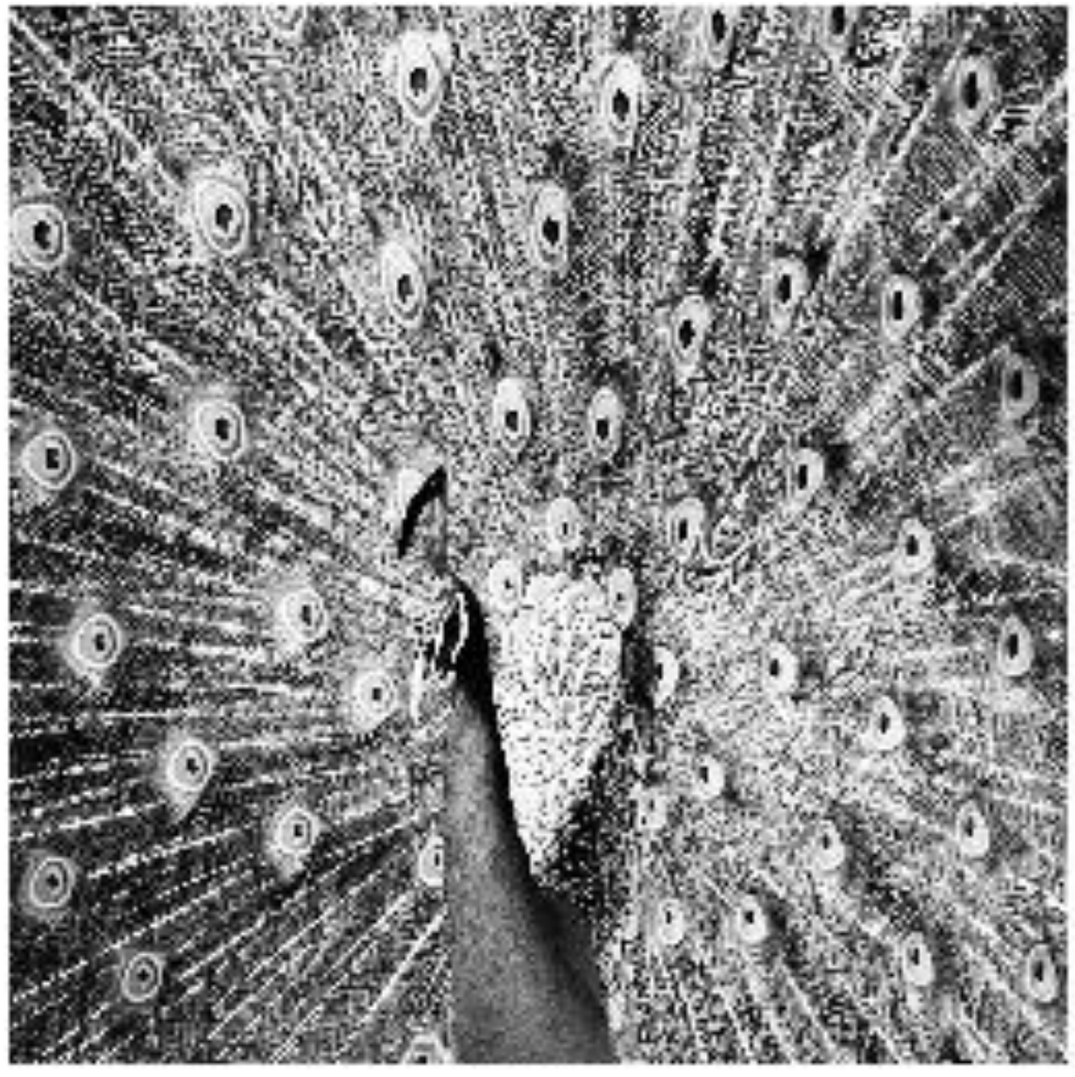


image H

Assignment #1 - problem 1(d)

- (d) Perform local histogram equalization on image D and output the result as L.

- Local histogram equalization
  I. 設window size
  II. 對圖中的每個點周圍在window範圍內的點算histogram
  III. 利用transfer function對該點做histogram equalization

$$y = f(x) = (L-1)\sum_{0}^{x_i} \frac{h(x_i)}{w \times h}$$

IV. 利用轉換後的灰階值對原圖進行equalization

Assignment #1 - problem 1(d)

- (d) Perform local histogram equalization on image D and output the result as L.

image D

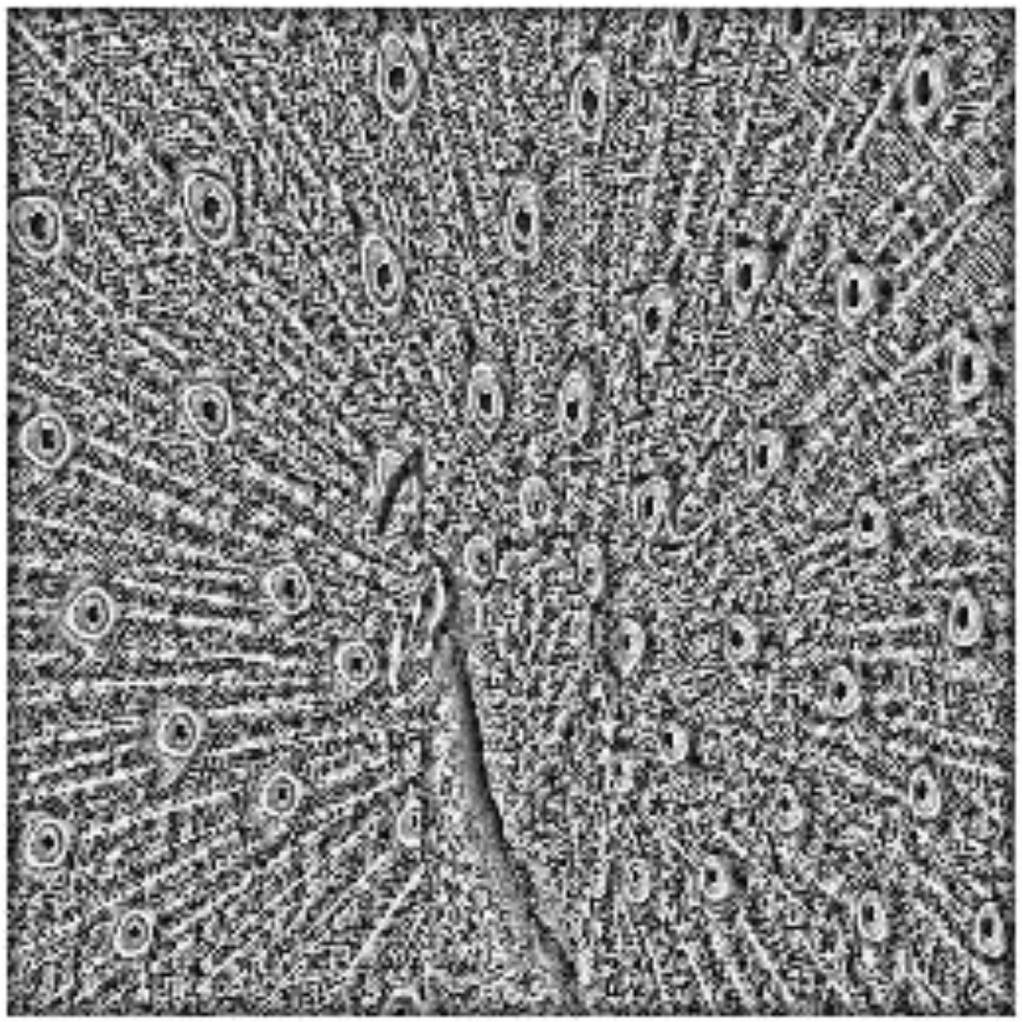
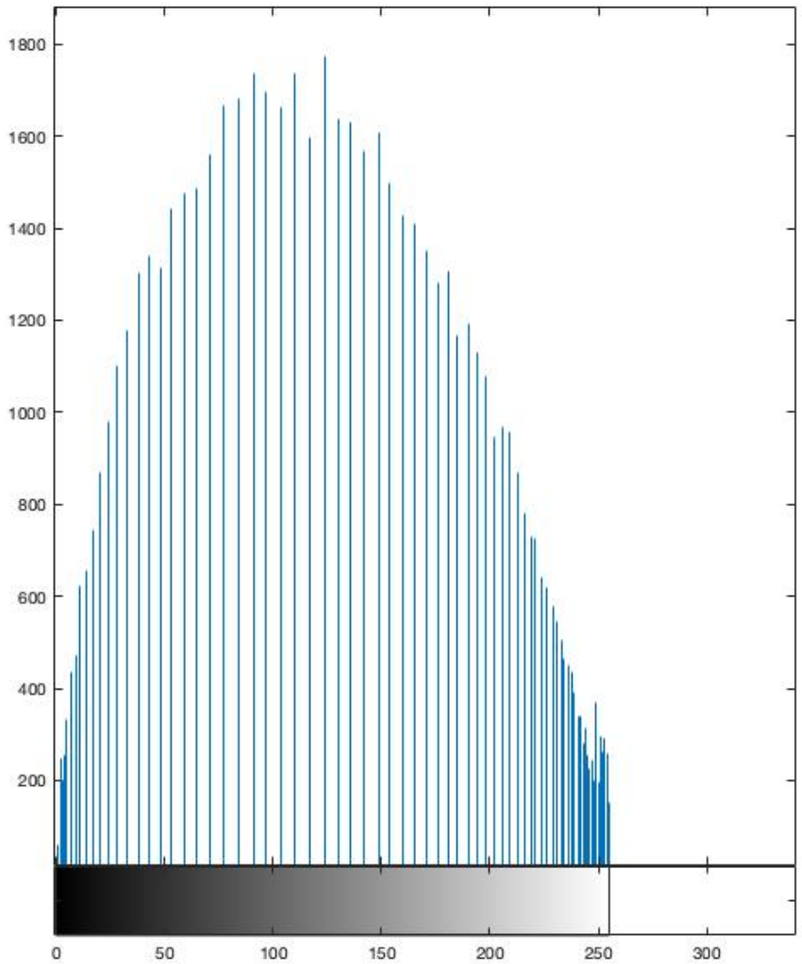


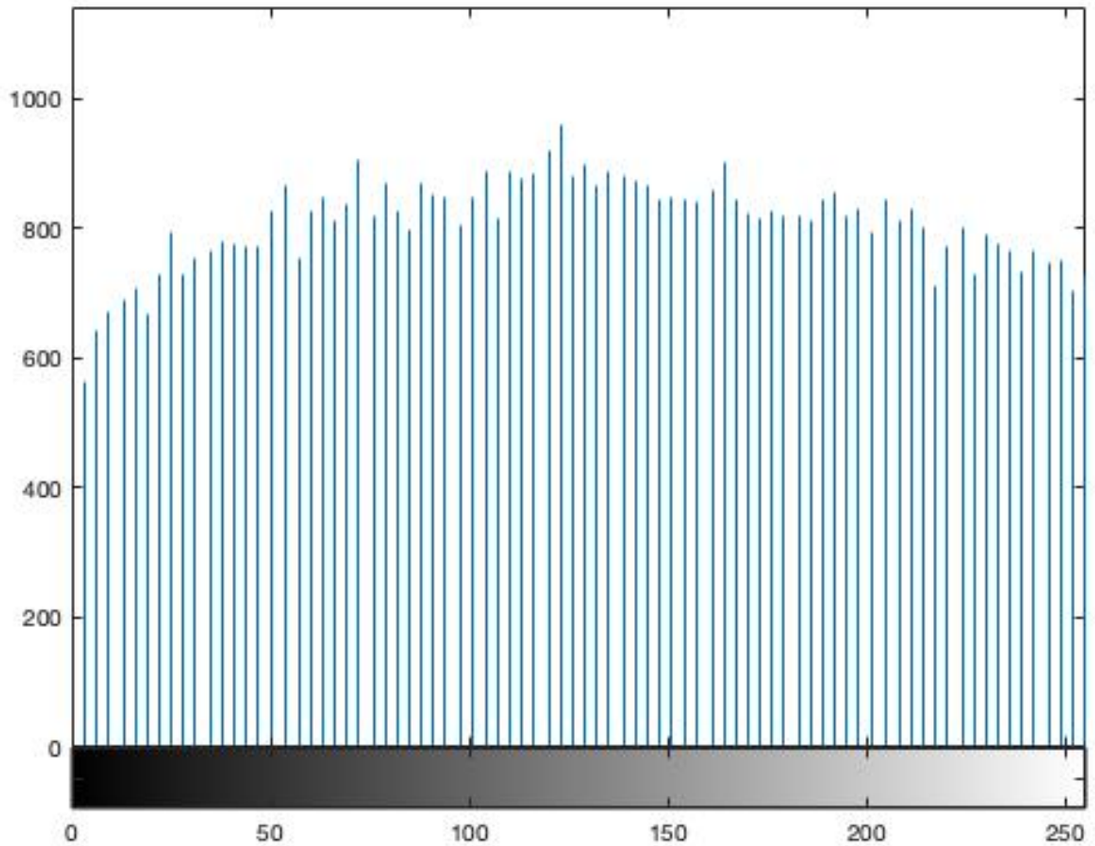
image L

Assignment #1 - problem 1(e)

- (e) Plot the histograms of H and L. What's the main difference between local and global histogram equalization?



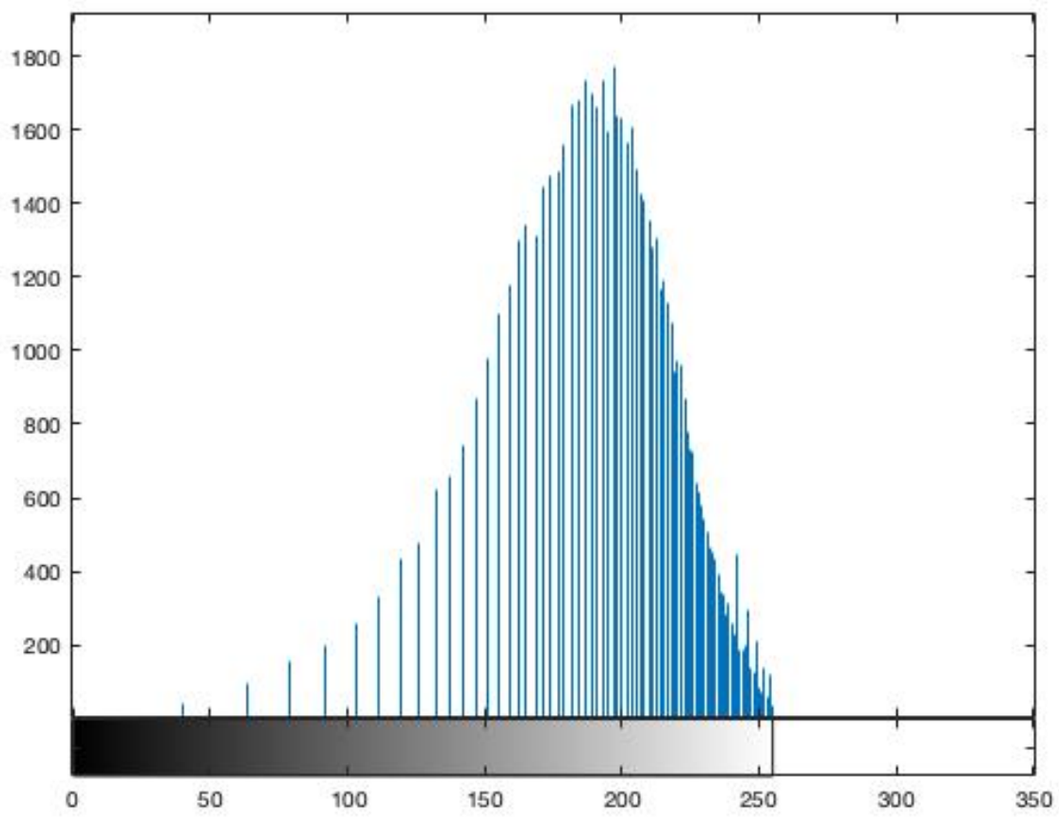
Histogram of H



Histogram of L

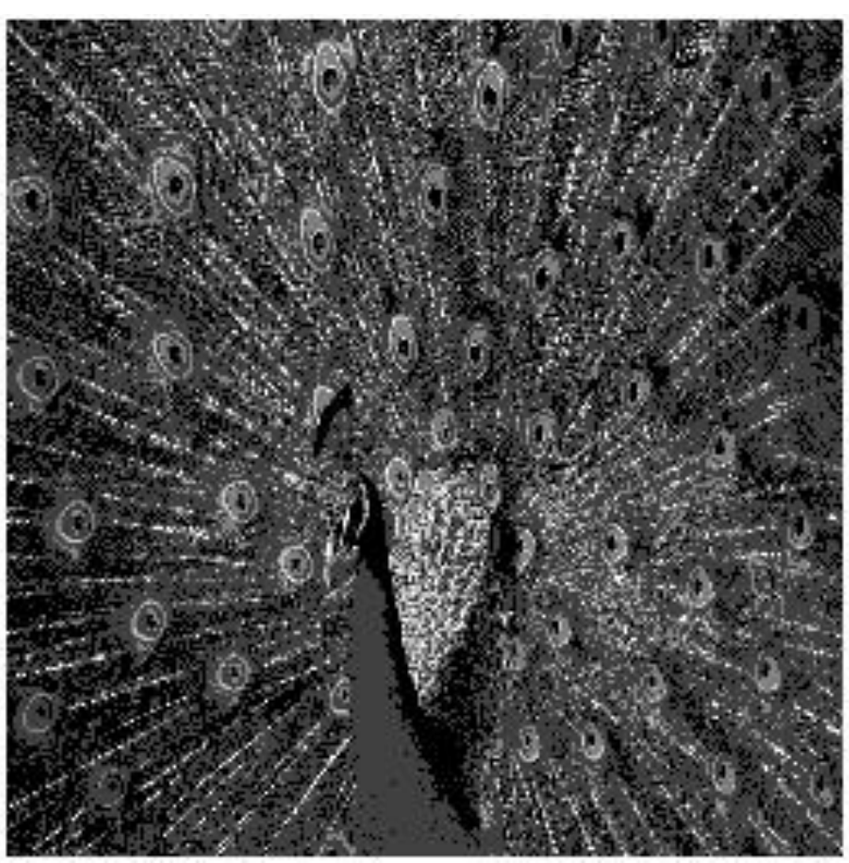
Assignment #1 - problem 1(f)

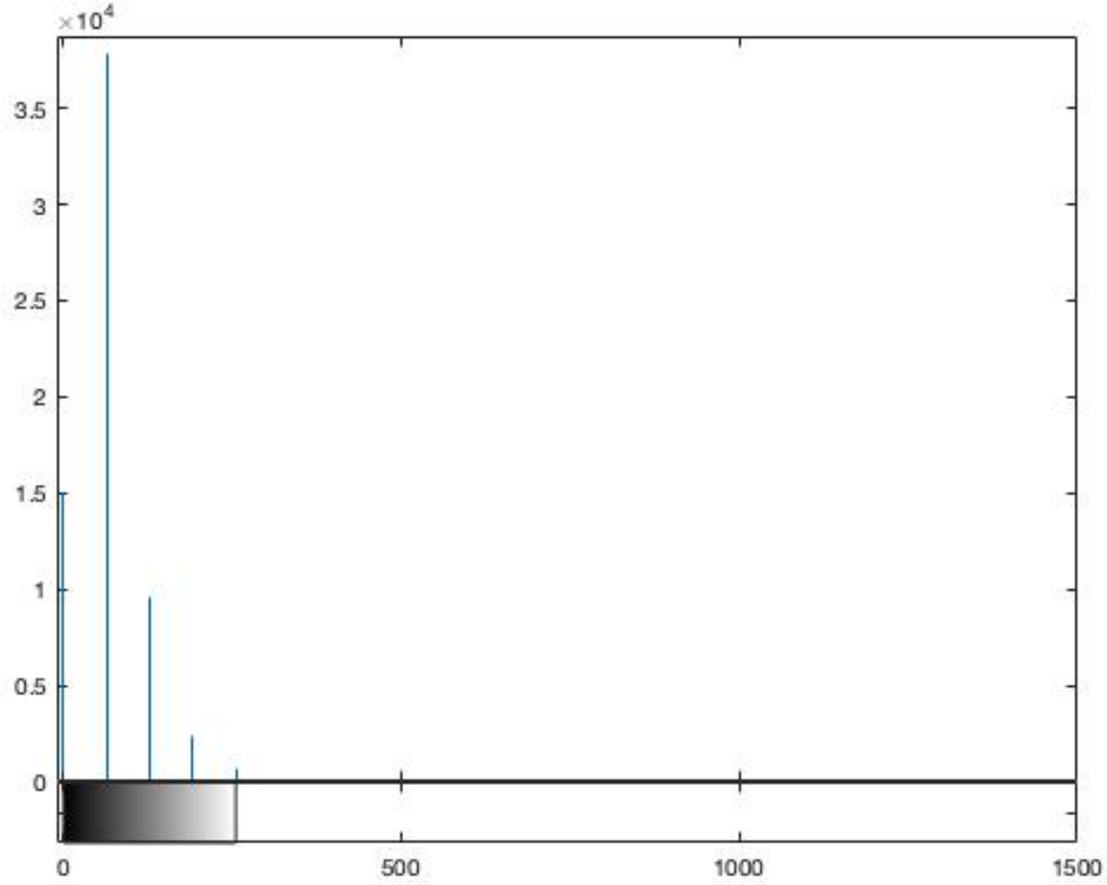
- (f) Perform the log transform, inverse log transform and power-law transform to enhance image D. Please adjust the parameters to obtain the results as best as you can. Show the parameters, resultant images and corresponding histograms. Provide some discussions on the results as well.
- log transform:
  G(i, j) = c * log(1 + F(i, j))，其中c = 255 / log(Fmax + 1)



Assignment #1 - problem 1(f)

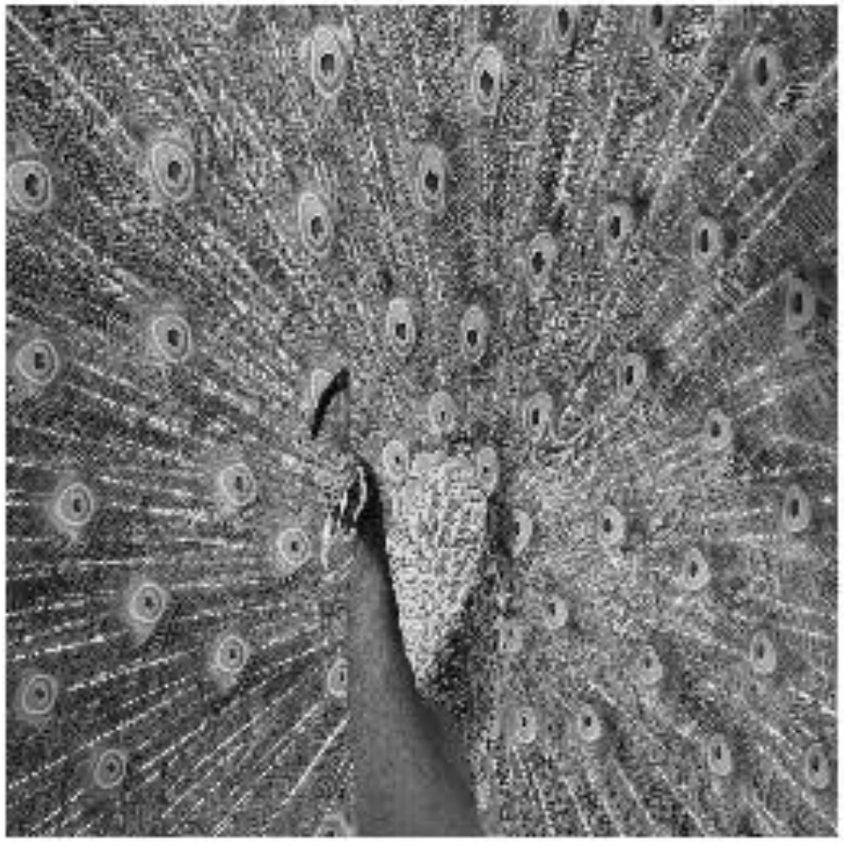
- (f) Perform the log transform, inverse log transform and power-law transform to enhance image D. Please adjust the parameters to obtain the results as best as you can. Show the parameters, resultant images and corresponding histograms. Provide some discussions on the results as well.
- inverse log transform:
  G(i, j) = c * (1.02 ^ F(i, j) - 1)，其中c = 255 / (1.02 ^ Fmax - 1)

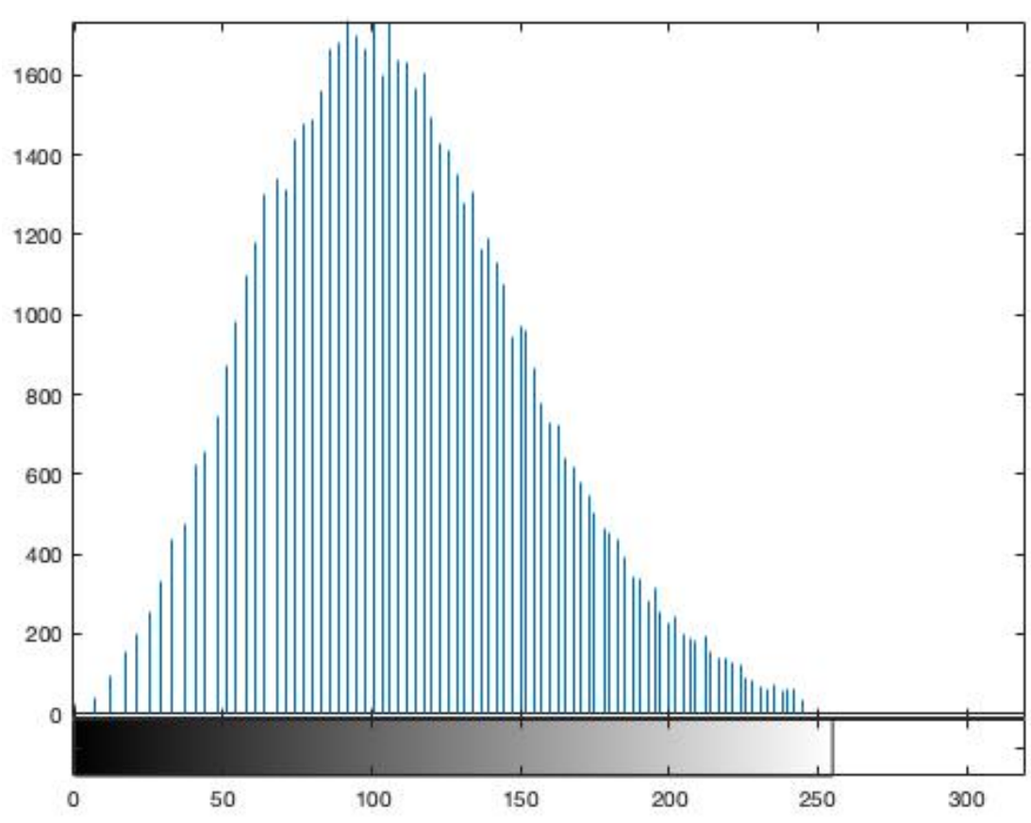




Assignment #1 - problem 1(f)

- (f) Perform the log transform, inverse log transform and power-law transform to enhance image D. Please adjust the parameters to obtain the results as best as you can. Show the parameters, resultant images and corresponding histograms. Provide some discussions on the results as well.
- power-law transform:
  G(i, j) = c * (F(i, j) ^ p)，其中c = 7, p = 0.8





Assignment #1 - problem 2-I(a)

- (a) Please generate two noisy images G_1, and G_2 by adding Gaussian noise to I_3 with different parameters. What's the main difference between these two images?
- noise = mean + var * randn(i, j)，其中randn(i, j)是normal distribution
- G(i, j) = I(i, j) + noise

image I3

image G1

Assignment #1 - problem 2-I(a)

- (a) Please generate two noisy images G_1, and G_2 by adding Gaussian noise to I_3 with different parameters. What's the main difference between these two images?
- G1的mean = 0, var = 15
- G2的mean = 0, var = 25

image G1

image G2

Assignment #1 - problem 2-I(b)

- (b) Please generate two noisy images S_1, and S_2 by adding salt-and-pepper noise to I_3 with different parameters. What's the main difference between these two images?

- $$\begin{cases} I(nim,i,j) = 0, & if\ uniform(0,1) < threshold \\ I(nim,i,j) = 255, & if\ uniform(0,1) > 1 - threshold \\ I(nim,i,j) = I(im,i,j), & otherwise \end{cases}$$

Assignment #1 - problem 2-I(b)

- (b) Please generate two noisy images S_1, and S_2 by adding salt-and-pepper noise to I_3 with different parameters. What's the main difference between these two images?

- S1的threshold = 0.01, S2的threshold = 0.1

image S1

image S2

Assignment #1 - problem 2-I(c)

- (c) Design proper filters to remove noise from G_1 and S_1, and denote the resultant images as R_G and R_S, respectively. Please detail the steps of the denoising process and specify corresponding parameters. Provide some discussions about the reason why those filters and parameters are chosen.
- Mean filter
  I. 設定一個window size
  II. 計算每個點周圍在window範圍內的點的平均
  III. 將平均值當作該點的新的pixel值

- PROS：可以消除高斯雜訊
  CONS：影像會變模糊

Assignment #1 - problem 2-I(c)

- (c) Design proper filters to remove noise from G_1 and S_1, and denote the resultant images as R_G and R_S, respectively. Please detail the steps of the denoising process and specify corresponding parameters. Provide some discussions about the reason why those filters and parameters are chosen.
- Mean filter

image G1

image RG
(window size = 3)

Assignment #1 - problem 2-I(c)

- (c) Design proper filters to remove noise from G_1 and S_1, and denote the resultant images as R_G and R_S, respectively. Please detail the steps of the denoising process and specify corresponding parameters. Provide some discussions about the reason why those filters and parameters are chosen.
- Median filter
  I. 設定一個window size
  II. 排序每個點周圍在window範圍內的點，找出中位數
  III. 將中位數當作該點的新的pixel值

- PROS：可以消除椒鹽雜訊，並保留邊緣
  CONS：不適合高頻太多的影像

Assignment #1 - problem 2-I(c)

- (c) Design proper filters to remove noise from G_1 and S_1, and denote the resultant images as R_G and R_S, respectively. Please detail the steps of the denoising process and specify corresponding parameters. Provide some discussions about the reason why those filters and parameters are chosen.
- Median filter

image S1

image RS
(window size = 3)

Assignment #1 - problem 2-I(d)

- (d) Compute the PSNR values of R_G and R_S and provide some discussions.

- $$MSE = \frac{1}{w*h}\sum_{j}\sum_{k}\left[F(j,k) - F'(j,k)\right]^2$$

$$PSNR = 10 \times \log_{10}\left(\frac{255^2}{MSE}\right)$$

- 2張影像間的PSNR值越大，表示越相似

Assignment #1 - problem 2-I(d)

- (d) Compute the PSNR values of R_G and R_S and provide some discussions.

- G1和原圖的PSNR = 24.6697
  RG和原圖的PSNR = 26.0043

- S1和原圖的PSNR = 22.2492
  RS和原圖的PSNR = 29.1792

Assignment #1 - problem 2-II

- (II) Design your own method to remove the wrinkles on the face of a given image I_4 as shown in Fig. 3(b) and make it as pretty as you can. Please describe the steps of your process in detail and provide some discussions as well.

- 利用mean filter進行濾波，window size設為9

image I4

remove wrinkles

Assignment #2 - problem 1(a)

- (a) Given an image I_1 as show in Fig. 1(a), please perform 1st order edge detection, 2nd order edge detection, and Canny edge detection to obtain corresponding edge maps. Please describe each method in detail, specify each parameter clearly and discuss how each of them affects the resultant edge map. What are pros and cons of each method? [Please output the edge points with intensity value 1 and background points with intensity value 0.]

1st order edge detection

- Row gradient

$$G_R(j,k) = \frac{1}{K+2}\left[\left(A_2 + KA_3 + A_4\right) - \left(A_0 + KA_7 + A_6\right)\right]$$

- Column gradient

$$G_C(j,k) = \frac{1}{K+2}\left[\left(A_0 + KA_1 + A_2\right) - \left(A_6 + KA_5 + A_4\right)\right]$$

A_0	A_1	A_2
A_7	$F(j,k)$	A_3
A_6	A_5	A_4

- $G(j,k) = \sqrt{G_R^2(j,k) + G_C^2(j,k)}$

- K = 2: Sobel Mask

- If G(j, k) >= threshold => edge point
  If G(j, k) < threshold => non-edge point

2nd order edge detection

- 先用Laplacian mask算出二階梯度

$$H = \frac{1}{8}\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

- 如果鄰近兩點的二階梯度值一正一負，且相差的值大於等於threshold，視為edge point

Canny edge detector

- 使用Sobel mask計算Row gradient和Column gradient

$$G(j,k) = \sqrt{G_R^2(j,k) + G_C^2(j,k)}$$

- 計算角度，將角度分類到0, 45, 90, 135度之一

$$\theta(j,k) = \tan^{-1}\left(\frac{G_C(j,k)}{G_R(j,k)}\right)$$

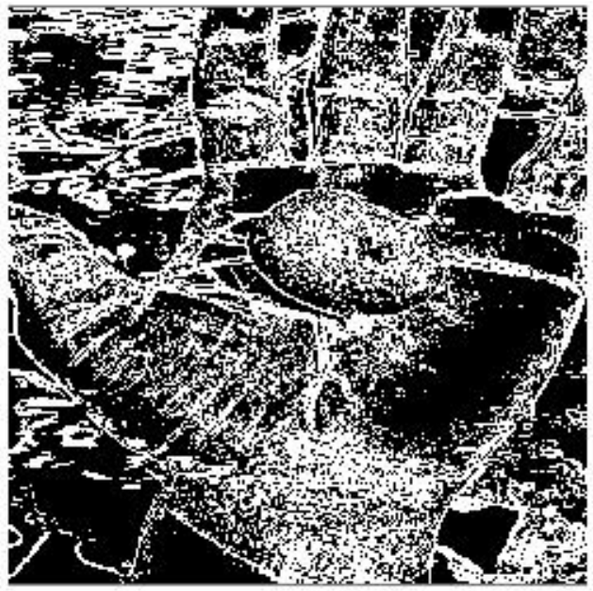
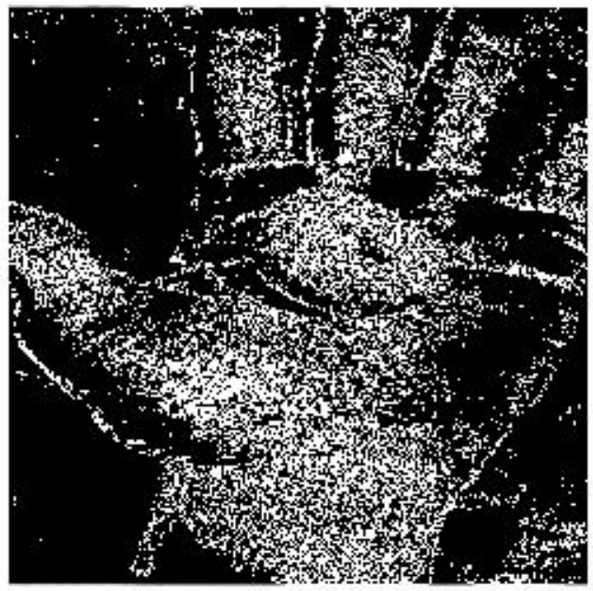
- Non-maximal suppression：
  依照算出的梯度方向，比對該方向的像素梯度。如果該像素梯度最大，則保留梯度值，否則將梯度值改為0

Canny edge detector

- Hysteretic thresholding：設兩個threshold Th, Tl
  - Gn(x, y) >= Th　　edge point
  - Th > Gn(x, y) >= Tl　　candidate
  - Gn(x, y) < Tl　　non-edge point

  - candidate：如果周圍8個相鄰像素，存在一個像素梯度大於Th，則該像素為edge point

- 1st & 2nd order threshold = 40;
  Canny low threshold = 30, high threshold = 70


- 1st & 2nd order threshold = 60;
  Canny low threshold = 50, high threshold = 100



- 1st & 2nd order threshold = 80;
  Canny low threshold = 70, high threshold = 120



- 1st & 2nd order threshold = 100;
  Canny low threshold = 90, high threshold = 140



Assignment #2 - problem 1(b)

- (b) Given an image I_2 with periodic noise as shown in Fig. 1(b), please design your own method to generate the edge map by avoiding obtaining edges of the noise. [Please output the edge points with intensity value 1 and background points with intensity value 0.]

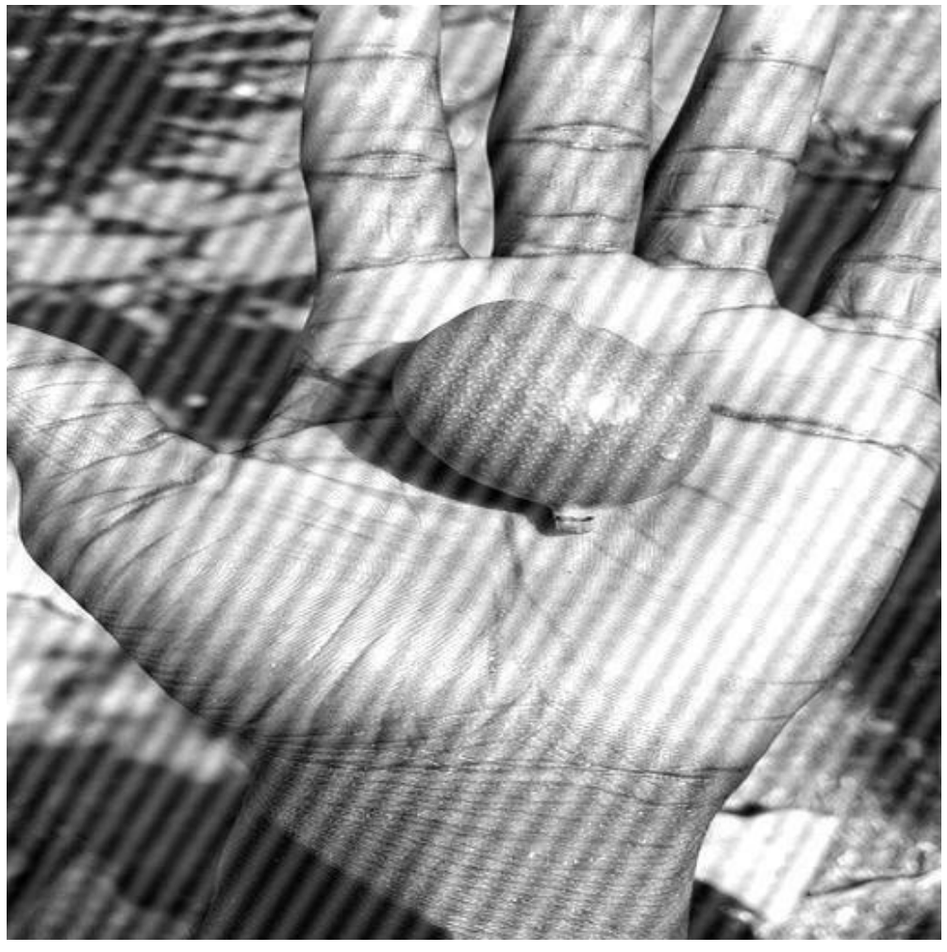
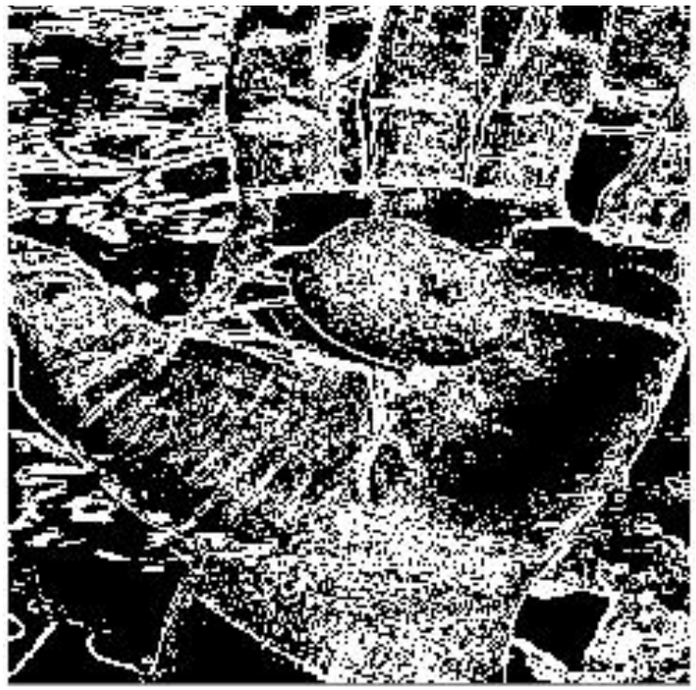


image I2

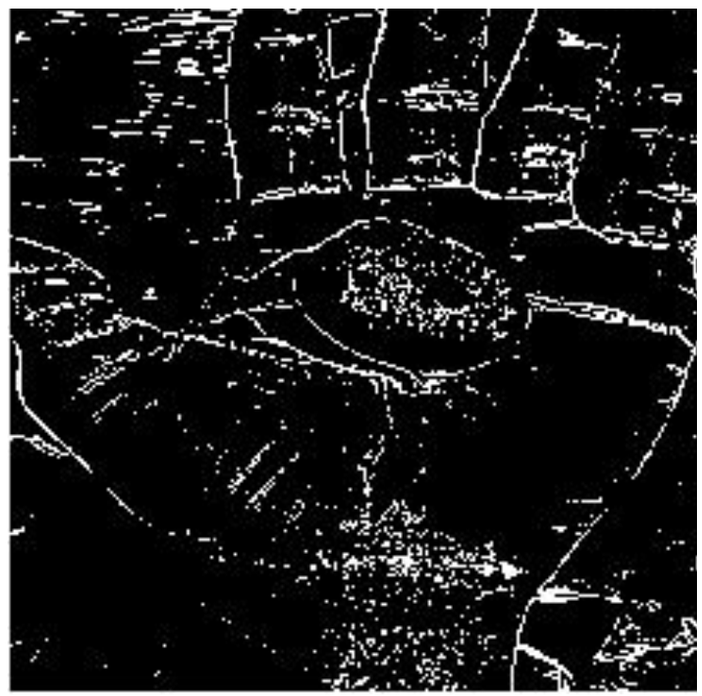
- 1st order edge detection



threshold = 40

threshold = 60

threshold = 80



threshold = 100

Assignment #2 - problem 2(a)

- (a) Please perform edge crispening on I_3 and denote the result as C. Show the parameters adopted and provide some discussions on the result as well.

- Edge -> high frequency
- High pass filter

$$H = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

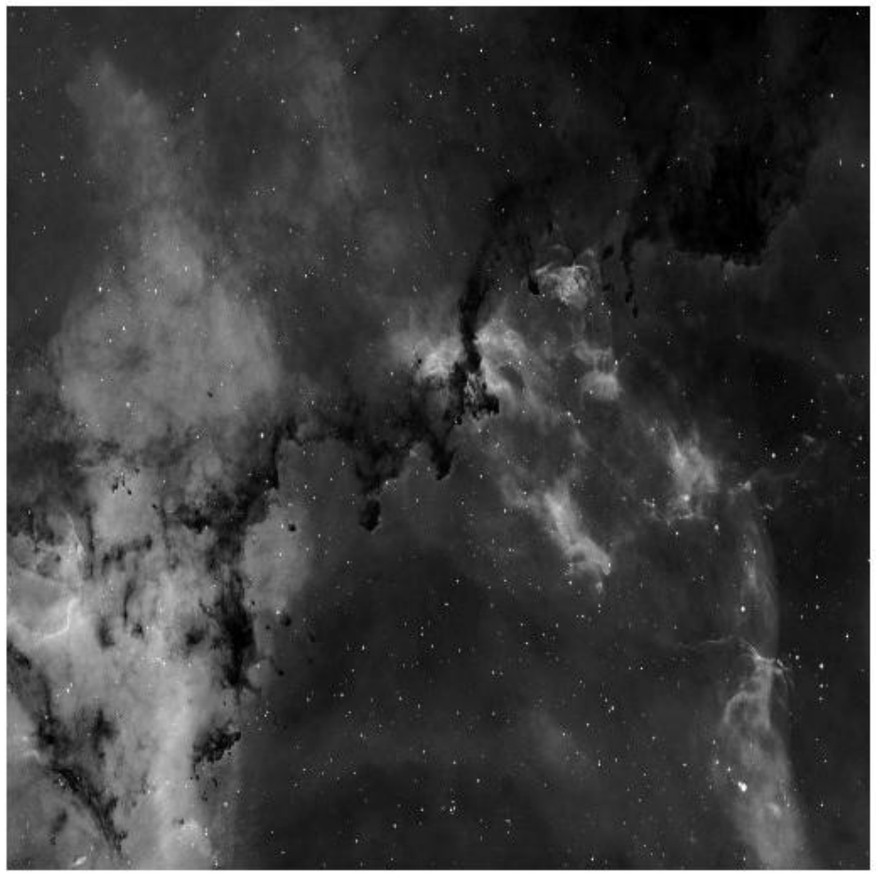


image I3

Assignment #2 - problem 2(a)

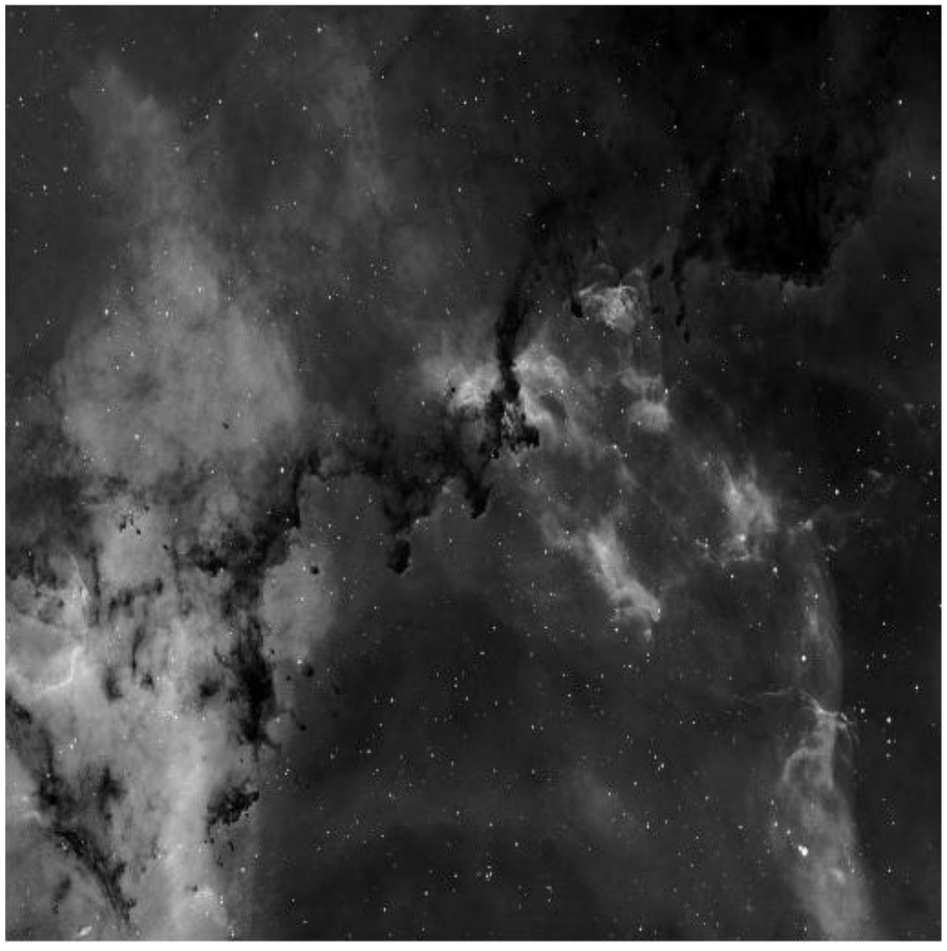


image I3

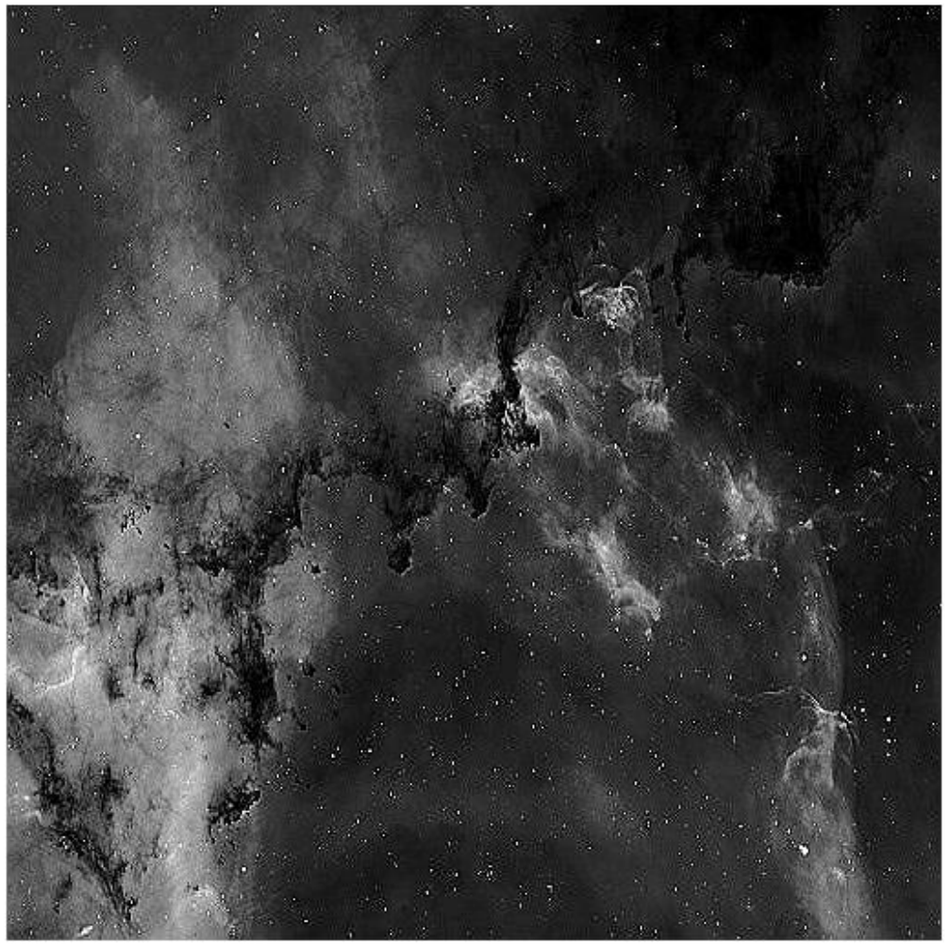


image C

Assignment #2 - problem 2(b)

- (b) Please design a warping function to convert the image C to image D with a shape similar to Fig. 2(b).

image C

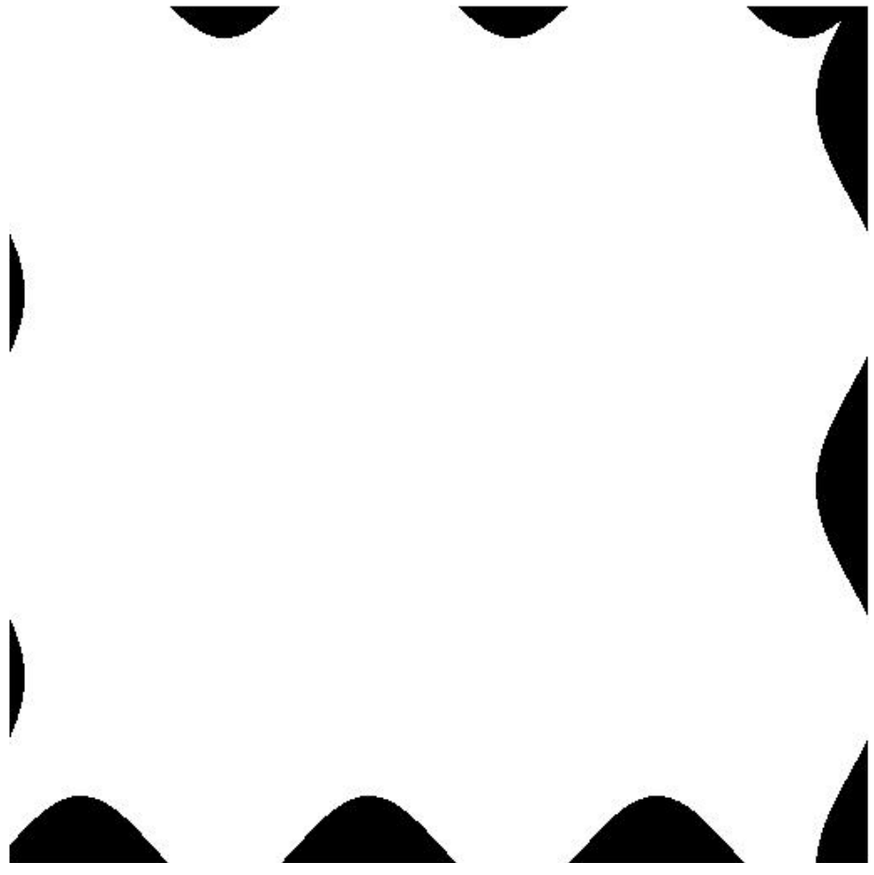


Fig. 2(b)

Assignment #2 - problem 2(b)

- (b) Please design a warping function to convert the image C to image D with a shape similar to Fig. 2(b).
- $$x = x' + a_x \cdot \sin\left(\frac{2\pi \cdot y'}{\tau_x}\right)$$
  $$y = y' + a_y \cdot \sin\left(\frac{2\pi \cdot x'}{\tau_y}\right)$$
- x, y是原圖座標，x’, y’是轉換後的座標

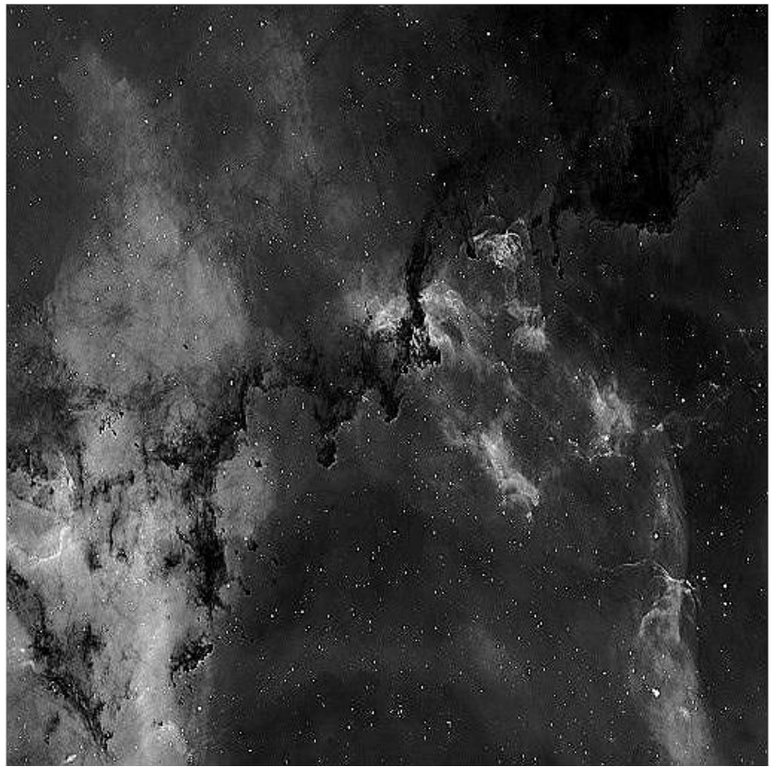
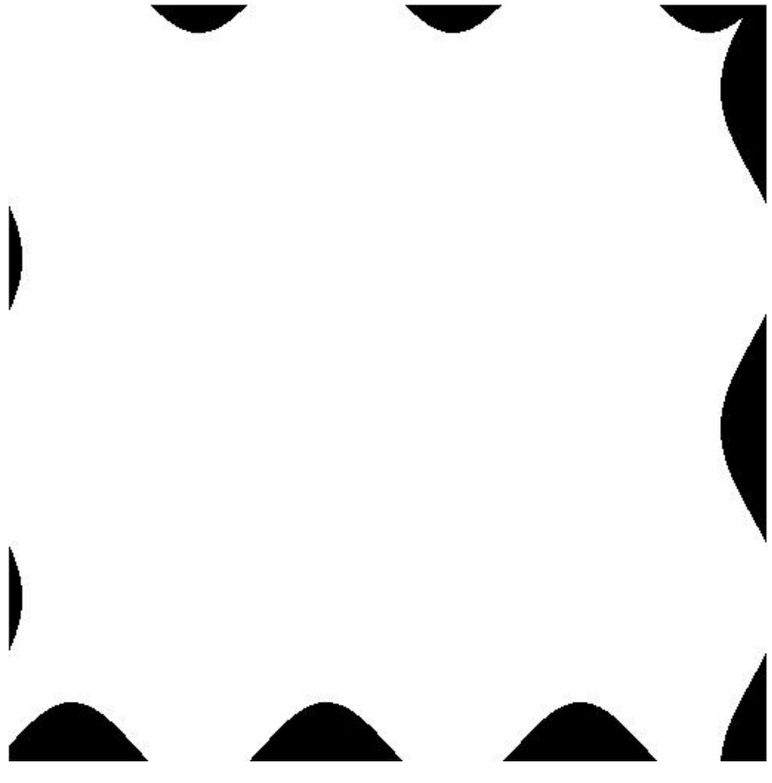


image C



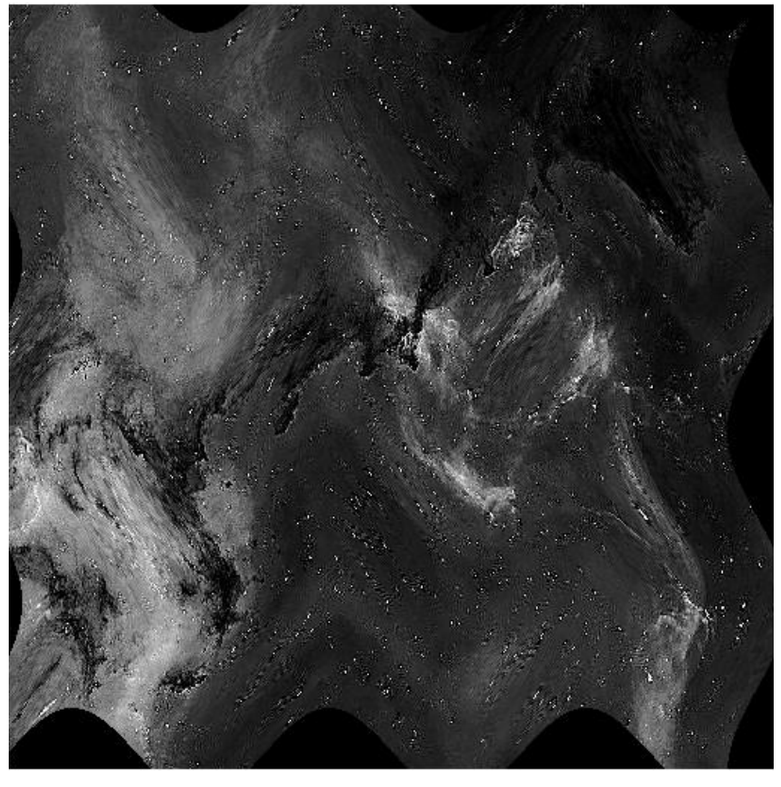
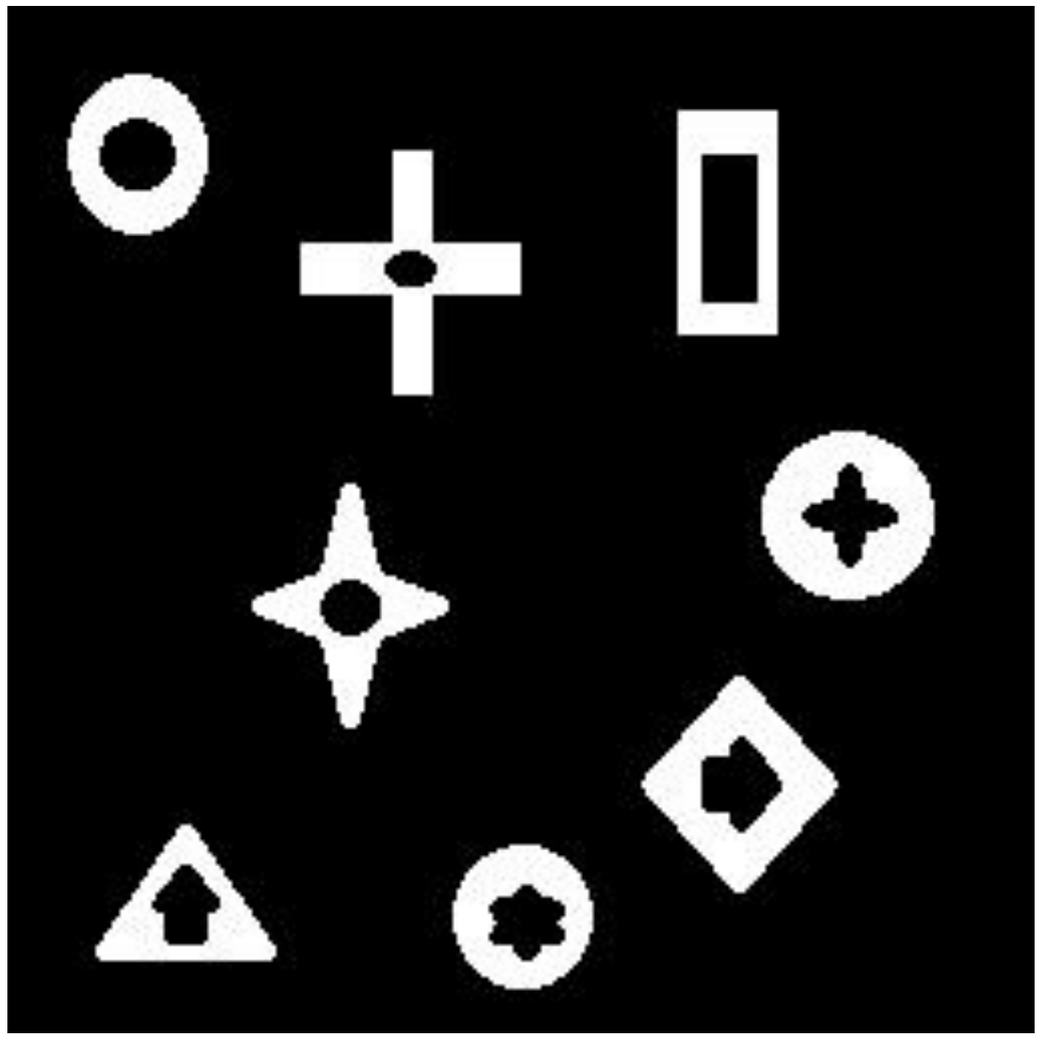


image D

Assignment #3 - problem 1(a)

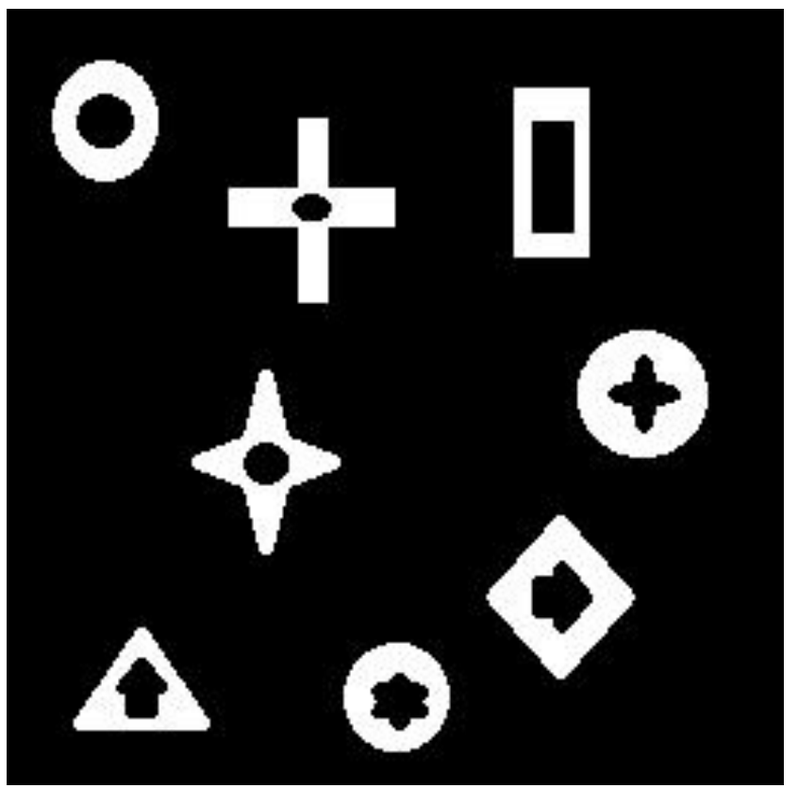
- (a) Perform boundary extraction on I_1 to extract the objects' boundaries and output the result as image B. Please provide some discussions about image B.



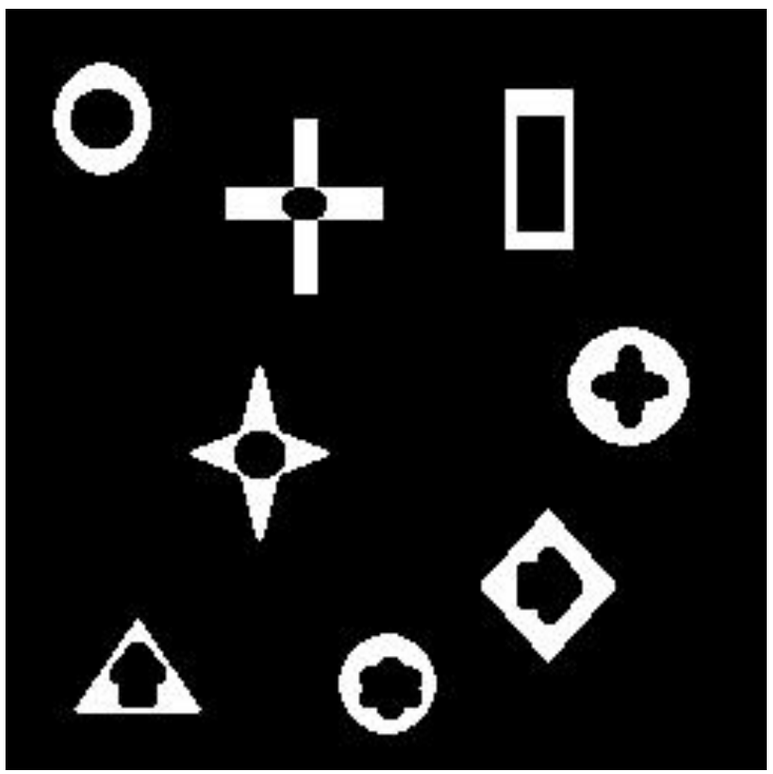
I1

Boundary Extraction

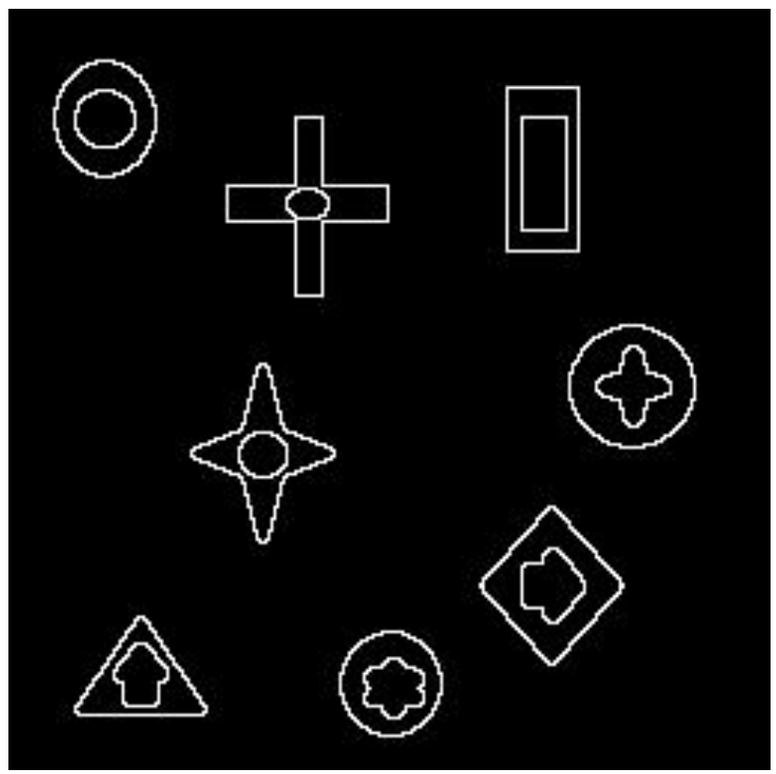
- $B(i,j) = I_1(i,j) - (I_1(i,j) \ominus H(i,j))$



I1



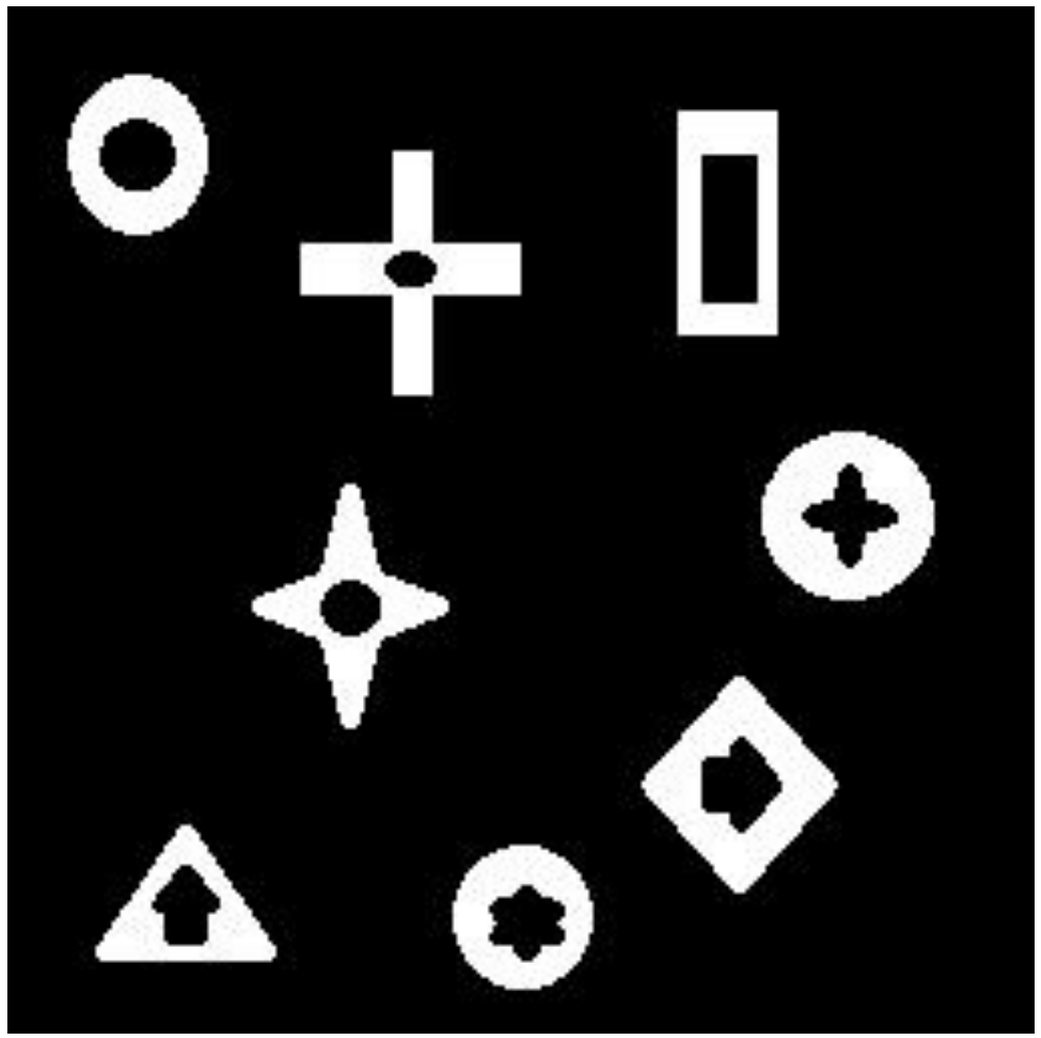
erosion of I1



B

Assignment #3 - problem 1(b)

- (b) Please design an algorithm to count the number of objects in I_1 based on morphological processing.



I1

Two-pass Connected-Component Labeling

- First pass

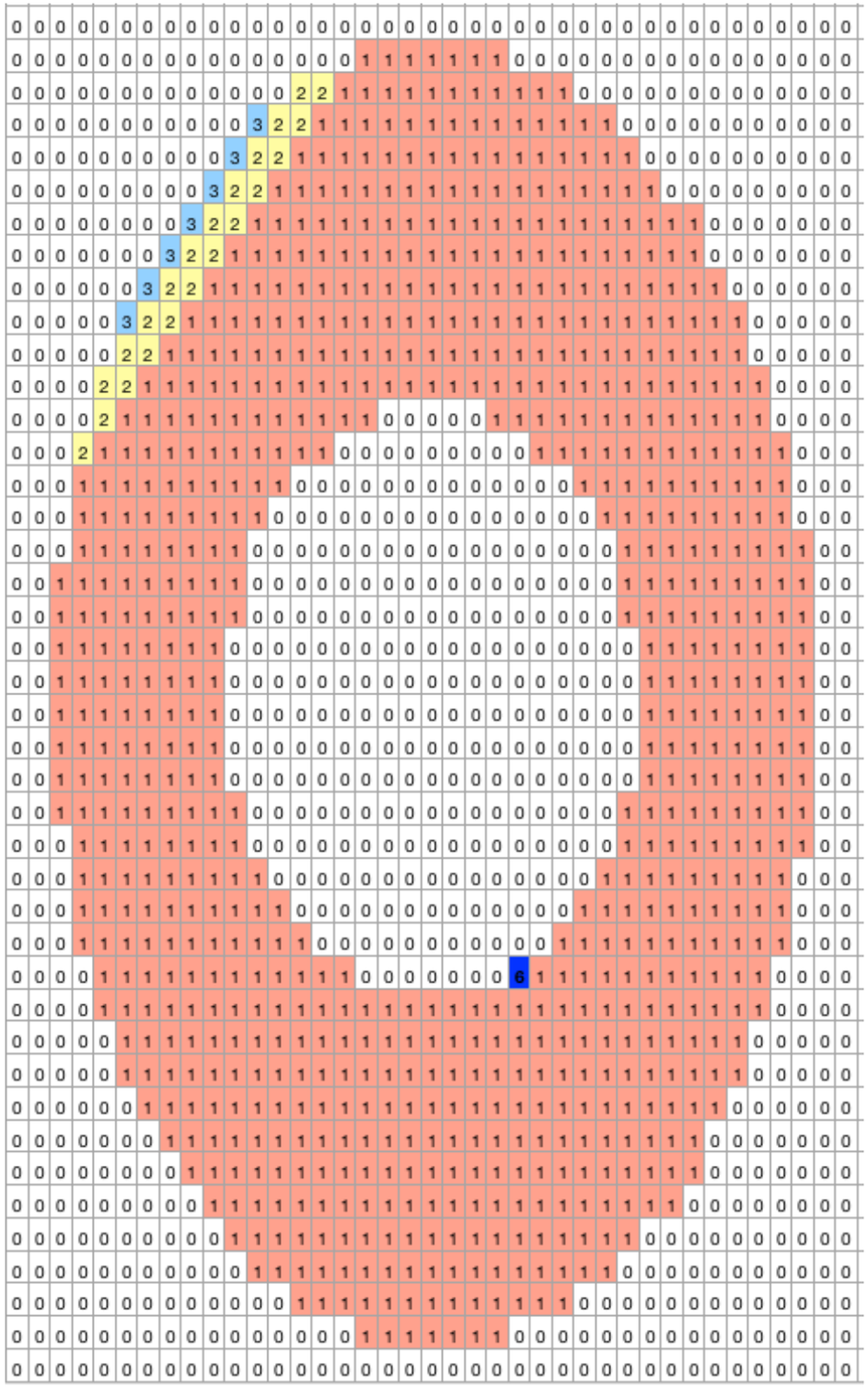
1. Iterate through each pixel of the image by column, then by row
2. If the pixel is not the background
   A. If there are no neighbors, uniquely label the current pixel
   B. Otherwise, find the neighbor with the smallest label and assign it to the current pixel, and store the equivalence between neighboring labels

- Second pass

1. Iterate through each pixel of the image by column, then by row
2. If the pixel is not the background
   A. Relabel the pixel with the lowest equivalent label

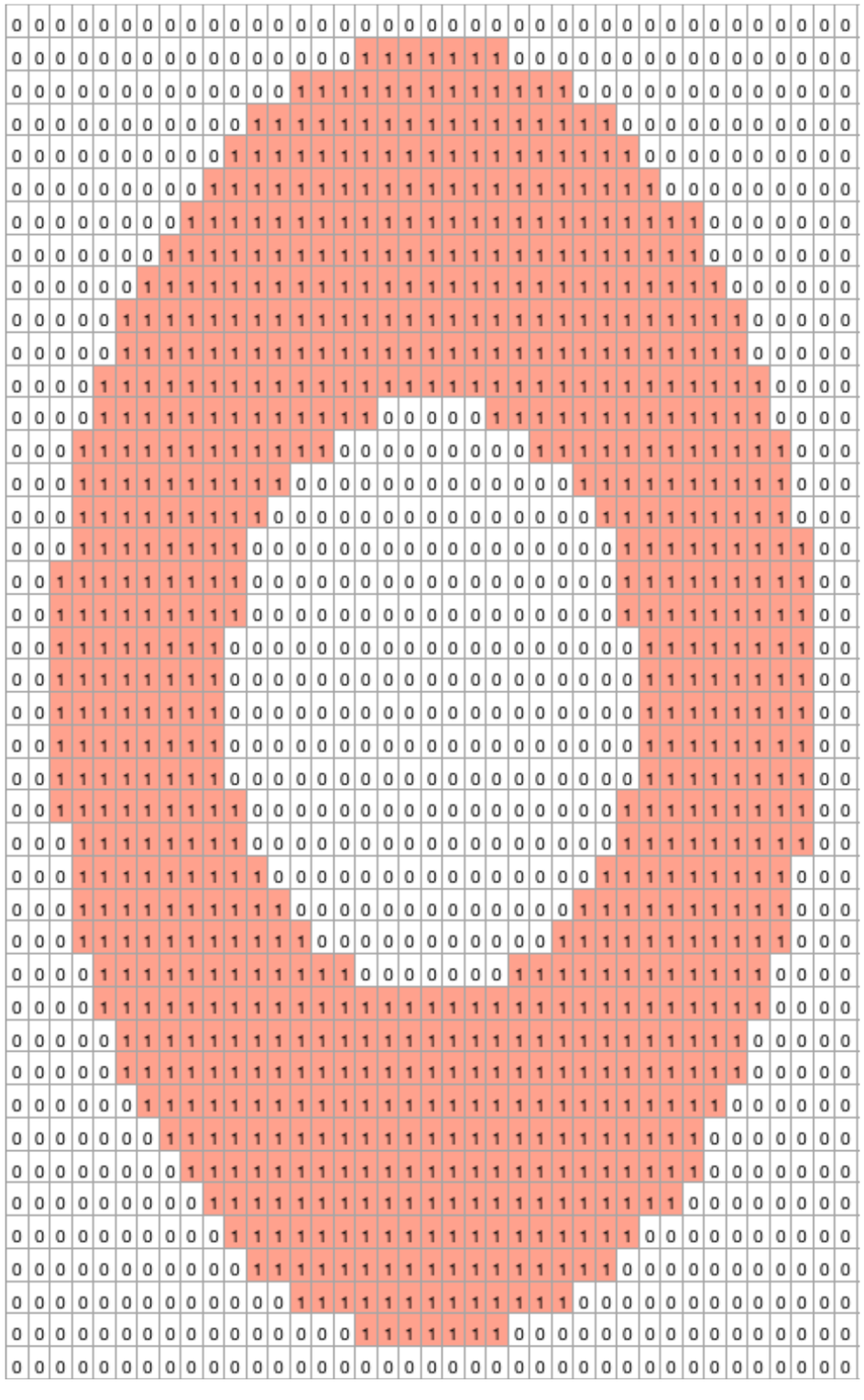
Two-pass Connected-Component Labeling

- First pass



Two-pass Connected-Component Labeling

- Second pass



Two-pass Connected-Component Labeling

- 兩次掃描標記
    1. 從上到下從左到右掃描，遇到目標像素時，檢查左上、上、右上、左邊四點
        A. 如果四個點都是0，該位置就標記為新的標記
        B. 如果四個點的非0值為相同的標記，該位置也標記為此相同標記
        C. 如果四個點的非0值為不同的標記，該位置標記為其中最小的標記，並記錄這些不同的標記，視為相同的連通元件
    2. 掃描整張影像，將視為相同的連通元件中的標記全部標記為該元件最小的標記。

Assignment #3 - problem 1(b)

- (b) Please design an algorithm to count the number of objects in I_1 based on morphological processing.

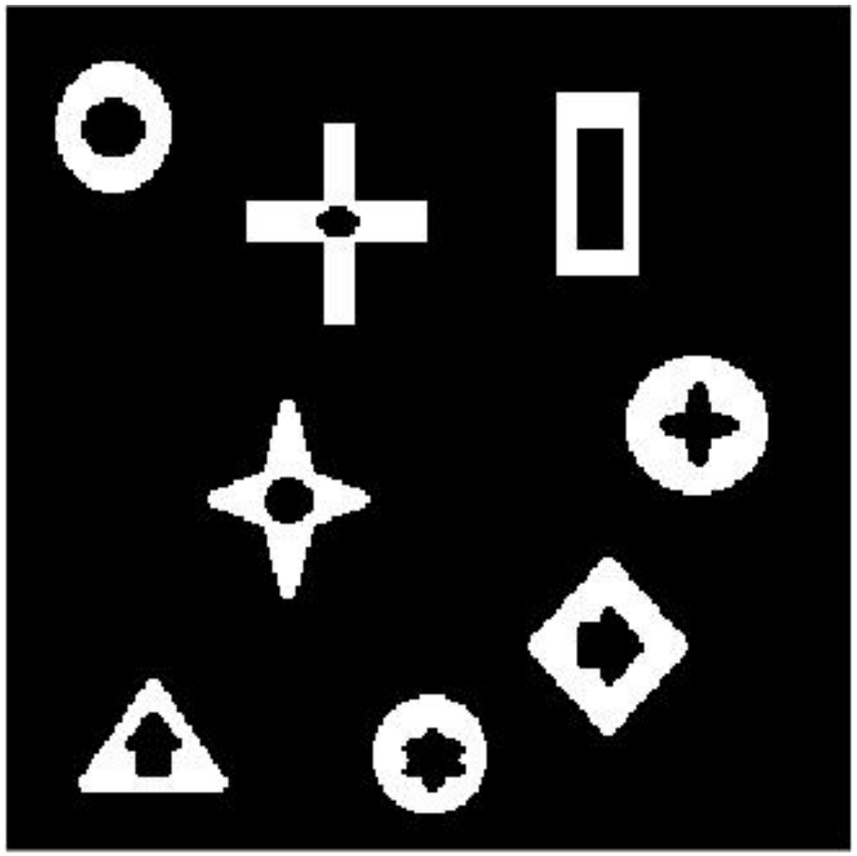


image I1

```
>> main
        Retrieving Image sample1.raw ...
        Retrieving Image sample2.raw ...
     8
```

Assignment #3 - problem 1(c)

- (c) Perform skeletonizing on I_1 and output the result as image S. Please provide some discussions about image S.

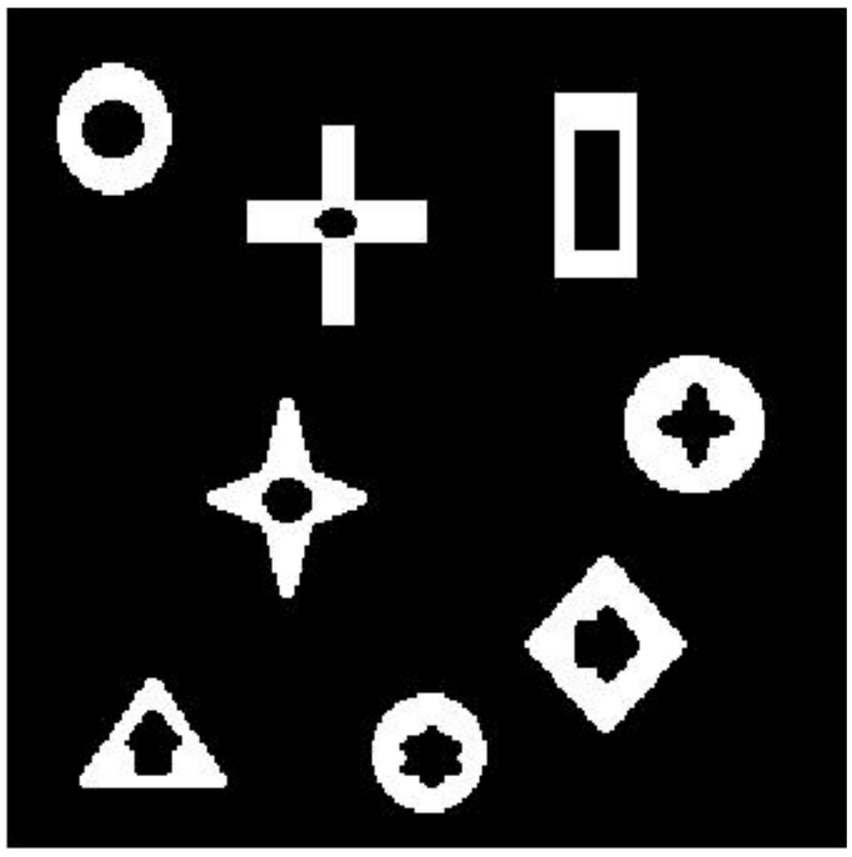


image I1

Skeleton

- Step I: Generate the conditional mask M(i ,j)
  - If M(i, j) == 1, it means (i, j) is a candidate for erase

TABLE 14.3-1. Shrink, Thin and Skeletonize Conditional Mark Patterns [M = 1 if hit]

Table	Bond	Pattern
		0 0 1 / 1 0 0 / 0 0 0 / 0 0 0
S	1	0 1 0 / 0 1 0 / 0 1 0 / 0 1 0
		0 0 0 / 0 0 0 / 1 0 0 / 0 0 1
		0 0 0 / 0 1 0 / 0 0 0 / 0 0 0
S	2	0 1 1 / 0 1 0 / 1 1 0 / 0 1 0
		0 0 0 / 0 0 0 / 0 0 0 / 0 1 0
		0 0 1 / 0 1 1 / 1 1 0 / 1 0 0 / 0 0 0 / 0 0 0 / 0 0 0 / 0 0 0
S	3	0 1 1 / 0 1 0 / 0 1 0 / 1 1 0 / 1 1 0 / 0 1 0 / 0 1 0 / 0 1 1
		0 0 0 / 0 0 0 / 0 0 0 / 0 0 0 / 1 0 0 / 1 1 0 / 0 1 1 / 0 0 1
		0 1 0 / 0 1 0 / 0 0 0 / 0 0 0
TK	4	0 1 1 / 1 1 0 / 1 1 0 / 0 1 1
		0 0 0 / 0 0 0 / 0 1 0 / 0 1 0
		0 0 1 / 1 1 1 / 1 0 0 / 0 0 0
STK	4	0 1 1 / 0 1 0 / 1 1 0 / 0 1 0
		0 0 1 / 0 0 0 / 1 0 0 / 1 1 1

Bond: classification, narrow down the search space
Pattern: coded as an 8-bit symbol for a filter

$$\begin{bmatrix} X_3 & X_2 & X_1 \\ X_4 & X & X_0 \\ X_5 & X_6 & X_7 \end{bmatrix} \otimes \begin{bmatrix} 2^{-4} & 2^{-3} & 2^{-2} \\ 2^{-5} & 2^{0} & 2^{-1} \\ 2^{-6} & 2^{-7} & 2^{-8} \end{bmatrix}$$

Skeleton

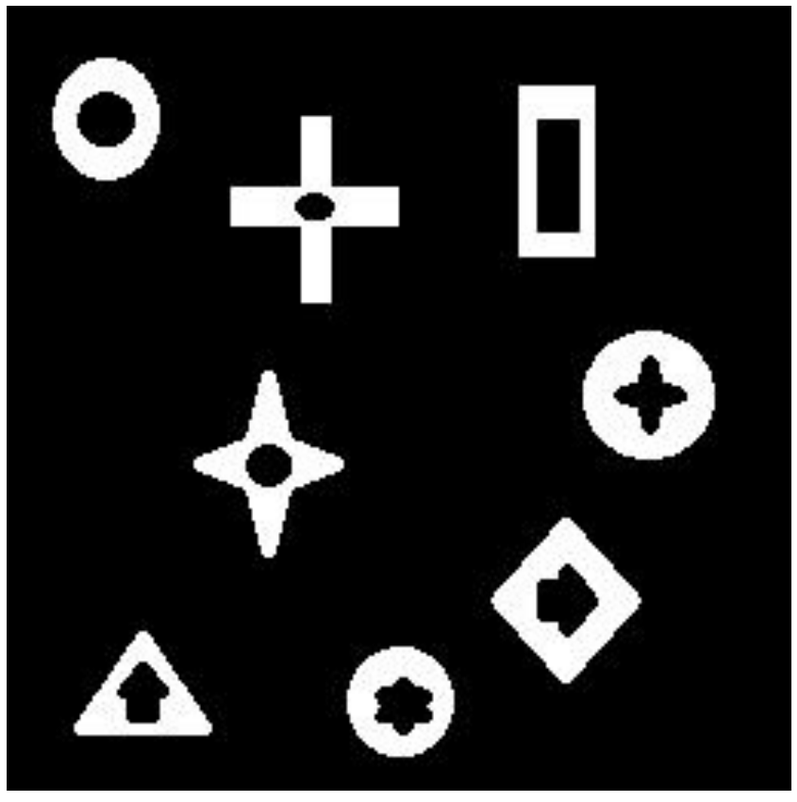
- Step II: Based on the conditional array, we decide whether to erase the candidate or not
  - If there's a hit, do nothing
  - Otherwise, erase it

TABLE 14.3-3. Skeletonize Unconditional Mark Patterns
$[P(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7) = 1 \text{ if hit}]^a$ $\quad A \cup B \cup C = 1, \quad D = 0 \cup 1$

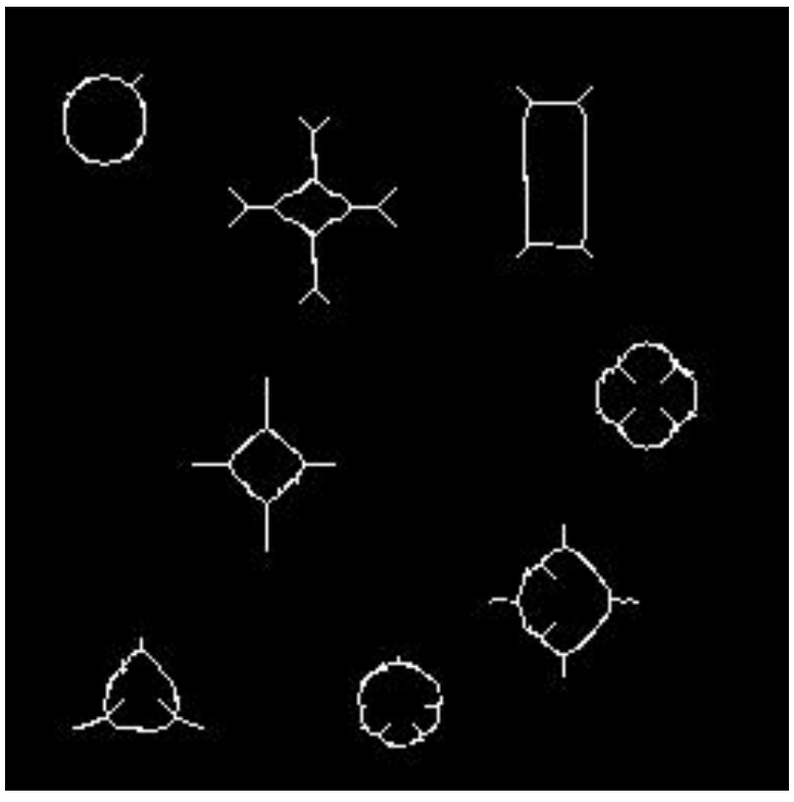
Pattern											
Spur											
0	0	0	0	0	0	0	0	*M*	*M*	0	0
0	*M*	0	*0*	*M*	0	0	*M*	0	0	*M*	0
0	0	*M*	*M*	0	0	0	0	0	0	0	0
Single 4-connection											
0	0	0	0	0	0	0	0	0	0	*M*	0
0	*M*	0	0	*M*	*M*	*M*	*M*	0	0	*M*	0
0	*M*	0	0	0	0	0	0	0	0	0	0
L corner											
0	*M*	0	0	*M*	0	0	0	0	0	0	0
0	*M*	*M*	*M*	*M*	0	0	*M*	*M*	*M*	*M*	0
0	0	0	0	0	0	0	M	0	0	*M*	0

Assignment #3 - problem 1(c)

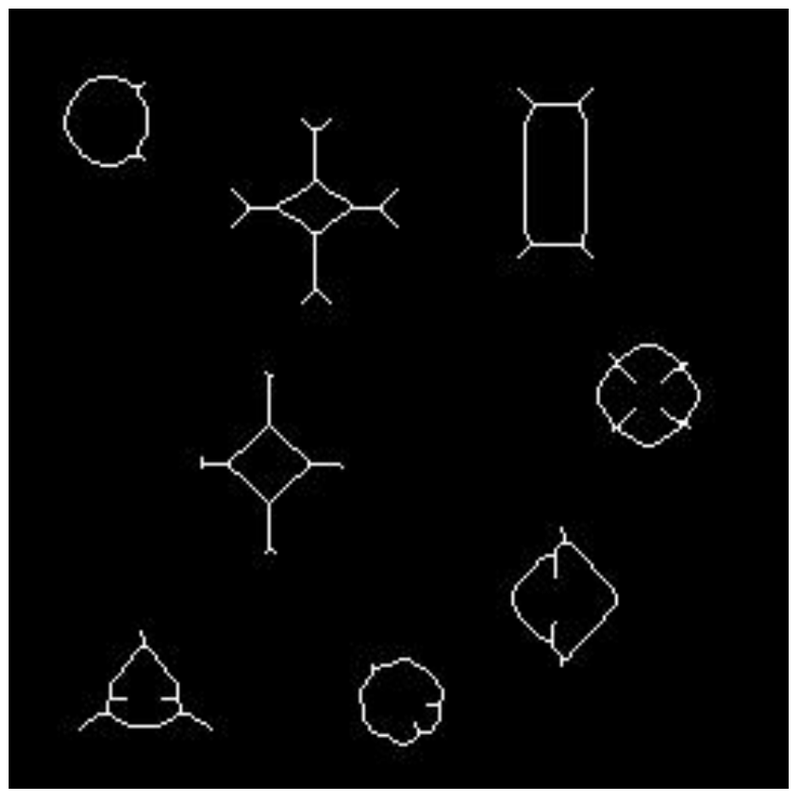
- (c) Perform skeletonizing on I_1 and output the result as image S. Please provide some discussions about image S.



input



output



output by matlab function

Assignment #3 - problem 2(a)

- (a) Perform Law's method on I_2 to segment the image into 3 different texture groups. Label the pixels of the same texture group with same intensity values. Please detail the method you choose, specify all the parameters and output the result as K.

image I2

Laws' method

- Step I: Convolution
  - $M_k(i,j) = F(i,j) \otimes H_k(i,j)$

$$H_1(i,j) = \frac{1}{36}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \quad H_2(i,j) = \frac{1}{12}\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \quad H_3(i,j) = \frac{1}{12}\begin{bmatrix} -1 & 2 & -1 \\ -2 & 4 & -2 \\ -1 & 2 & -1 \end{bmatrix}$$

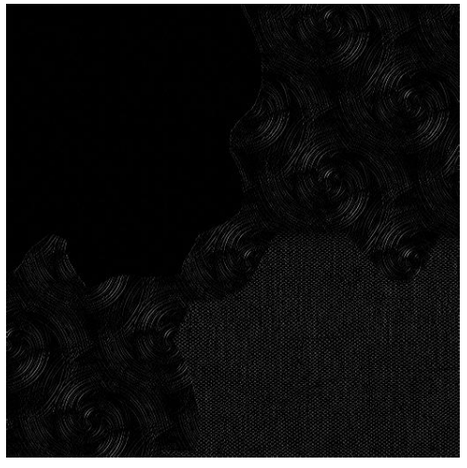
$$H_4(i,j) = \frac{1}{12}\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad H_5(i,j) = \frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix} \quad H_6(i,j) = \frac{1}{4}\begin{bmatrix} -1 & 2 & -1 \\ 0 & 0 & 0 \\ 1 & -2 & 1 \end{bmatrix}$$

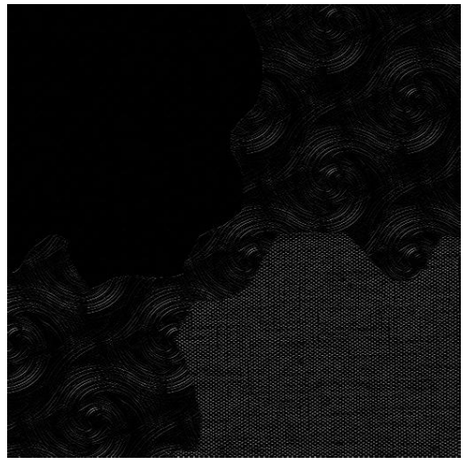
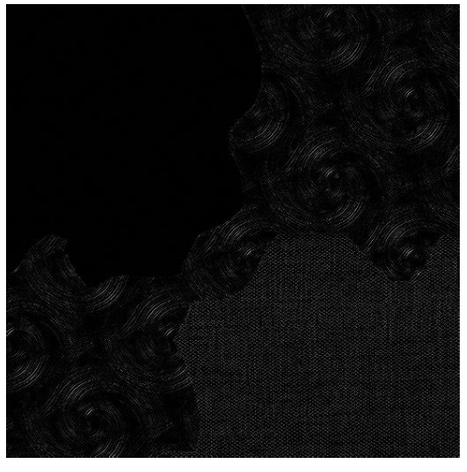
$$H_7(i,j) = \frac{1}{12}\begin{bmatrix} -1 & -2 & -1 \\ 2 & 4 & 2 \\ -1 & -2 & -1 \end{bmatrix} \quad H_8(i,j) = \frac{1}{4}\begin{bmatrix} -1 & 0 & 1 \\ 2 & 0 & -2 \\ -1 & 0 & 1 \end{bmatrix} \quad H_9(i,j) = \frac{1}{4}\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

Laws’ method



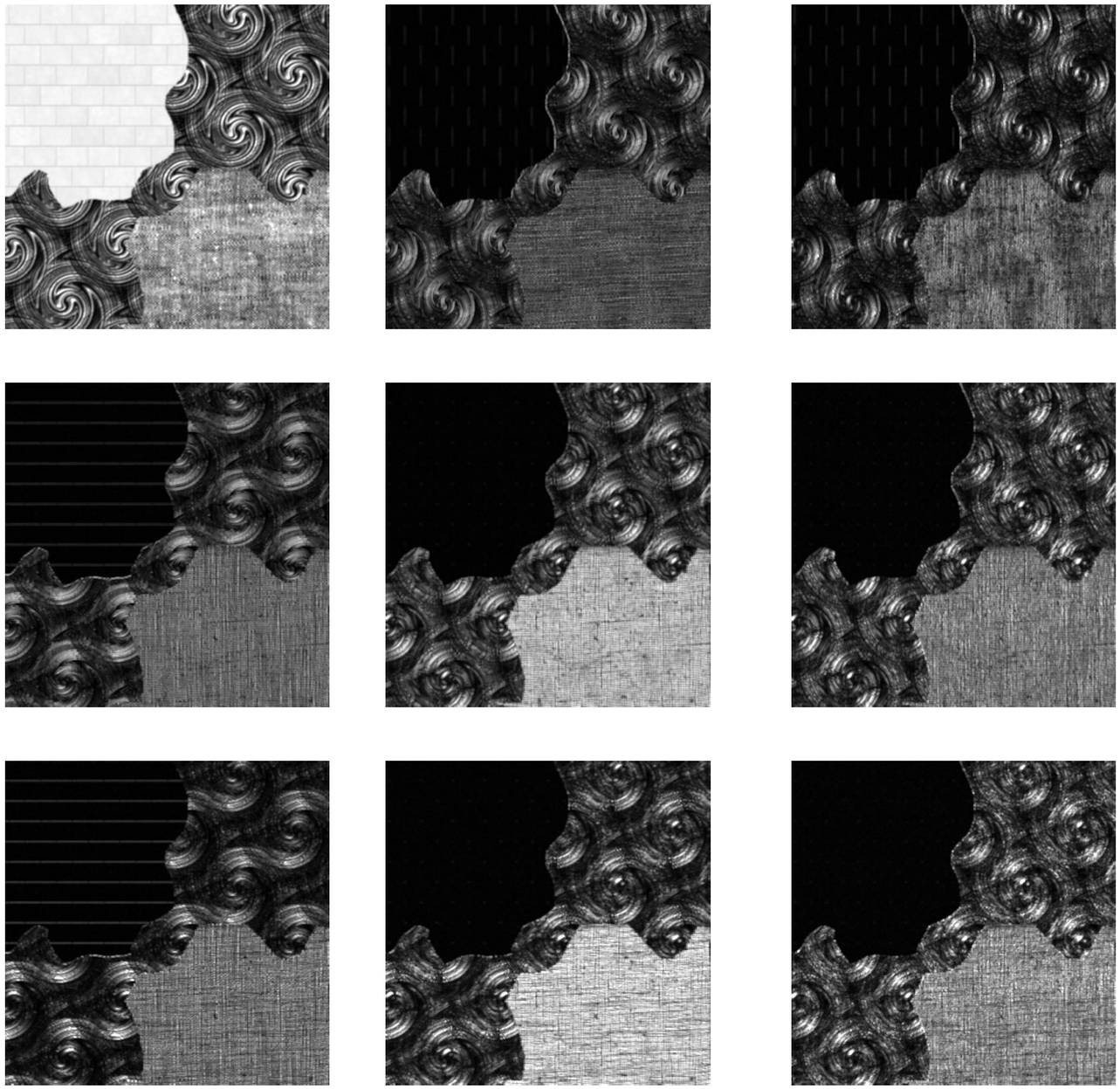


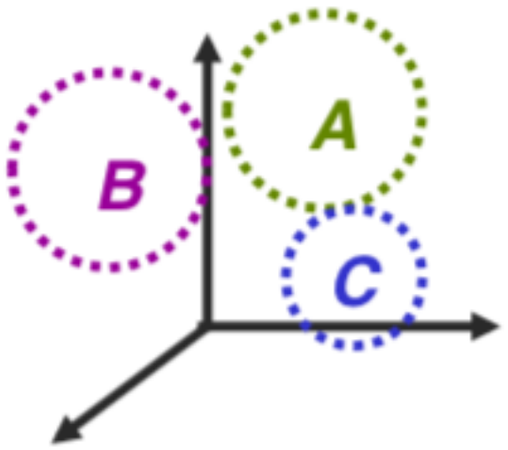
Laws' method

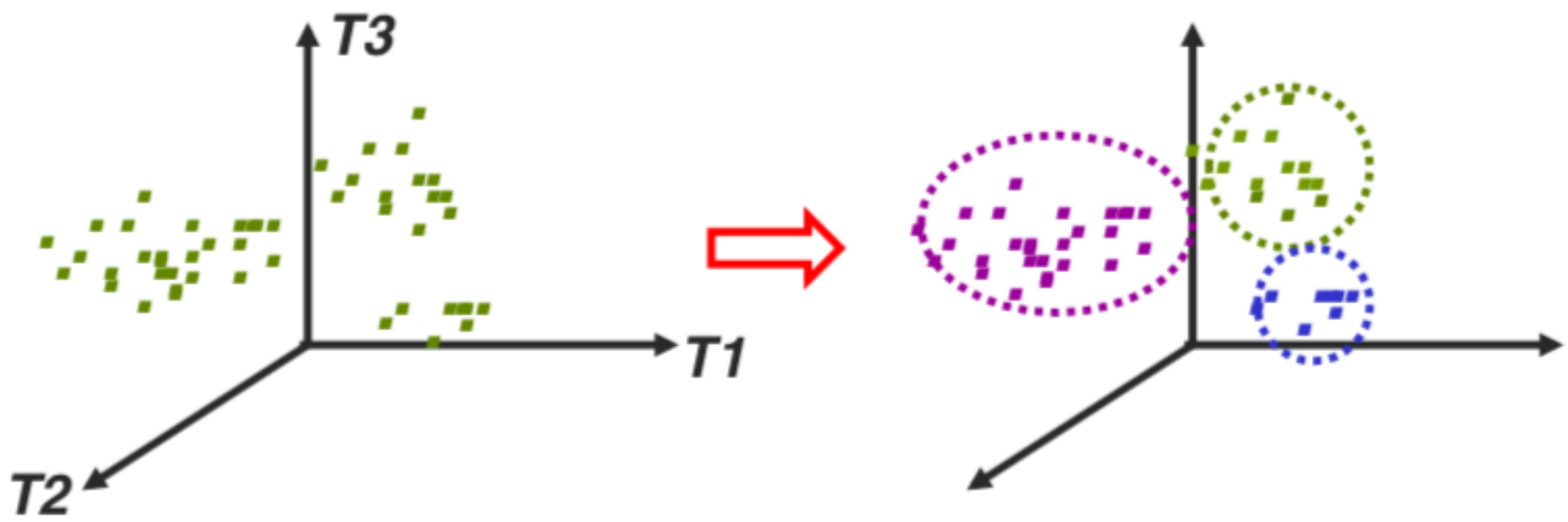
- Step II: Energy Computation
  - $T_k(i,j) = \sum\sum |M_k(i+m, j+n)|^2, (m,n) \in w$



Laws' method

- Given 9 feature sets, T1, T2, T3, …, T9
- Texture space -> 9 dimensional
- Use K-means algorithm to handle unsupervised classification problem





K-means algorithm

- Initialization
  - Select k vectors as the initial centroids
- Do the following iterations
  - Step I: Form k clusters using the NN rule
  - Step II: re-compute the centroid of each cluster

Assignment #3 - problem 2(a)

- window size = 11

- window size = 31

Assignment #3 - problem 2(a)

- window size = 41

- window size = 51

Assignment #3 - problem 2(b)

- (b) Based on K, try to generate another texture image by exchange the types of different texture patterns.

Image quilting by Efros & Freeman

- Step I: Tile the new texture image with blocks taken randomly from input texture

Image quilting by Efros & Freeman

- Step II: For every location, search the input texture for the block that have the least SSD(Sum of Squared Difference)

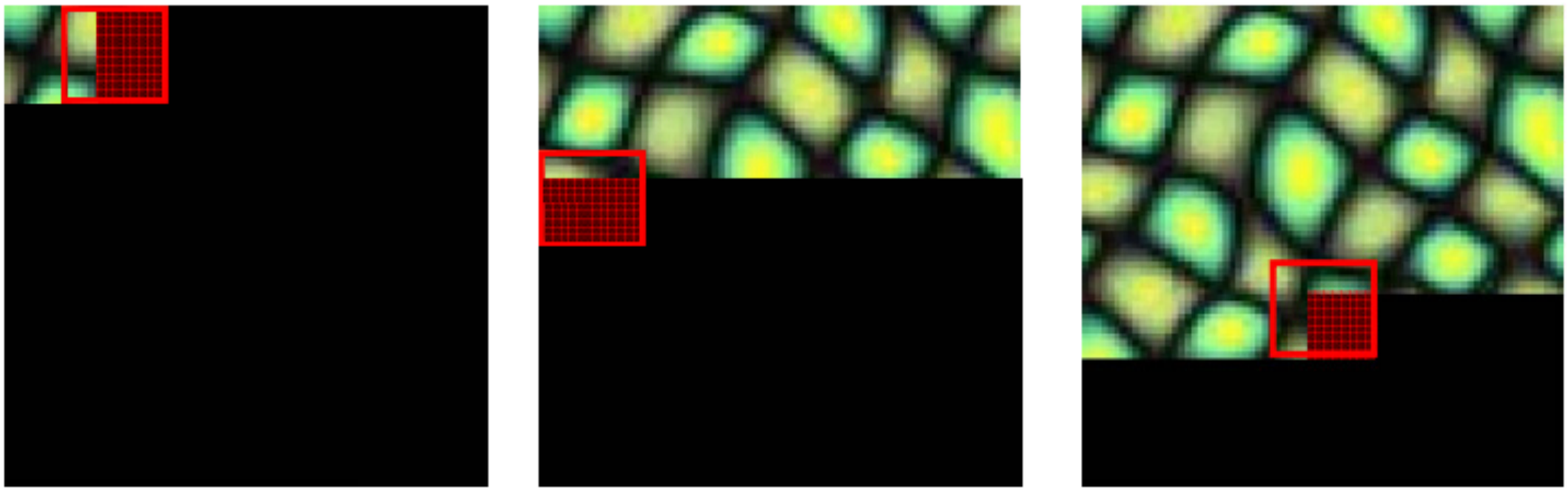


Image quilting by Efros & Freeman

- Step III: Compute the error surface between the newly chosen block and the old blocks at the overlap region. Find the minimum cost path along this surface and make that the boundary of the new block. Paste the block onto the texture

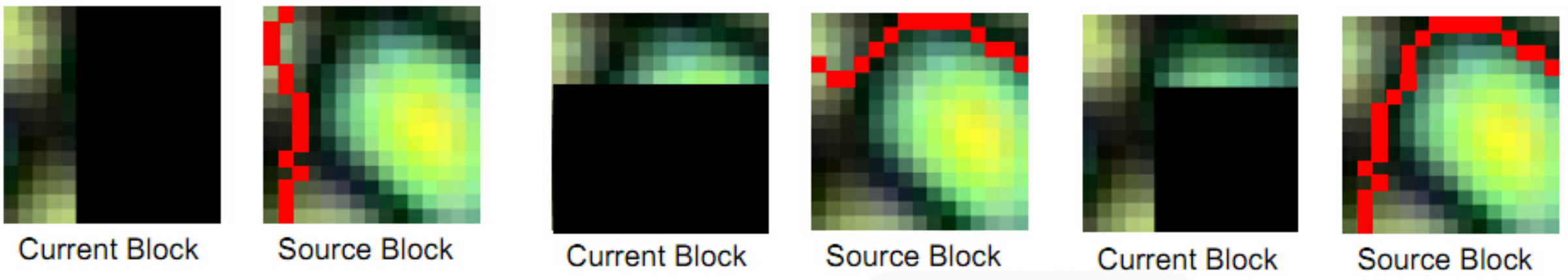


Image quilting by Efros & Freeman

- Texture 1

input image

size: 212 * 212
window size: 21
overlap size: 5

synthesis image

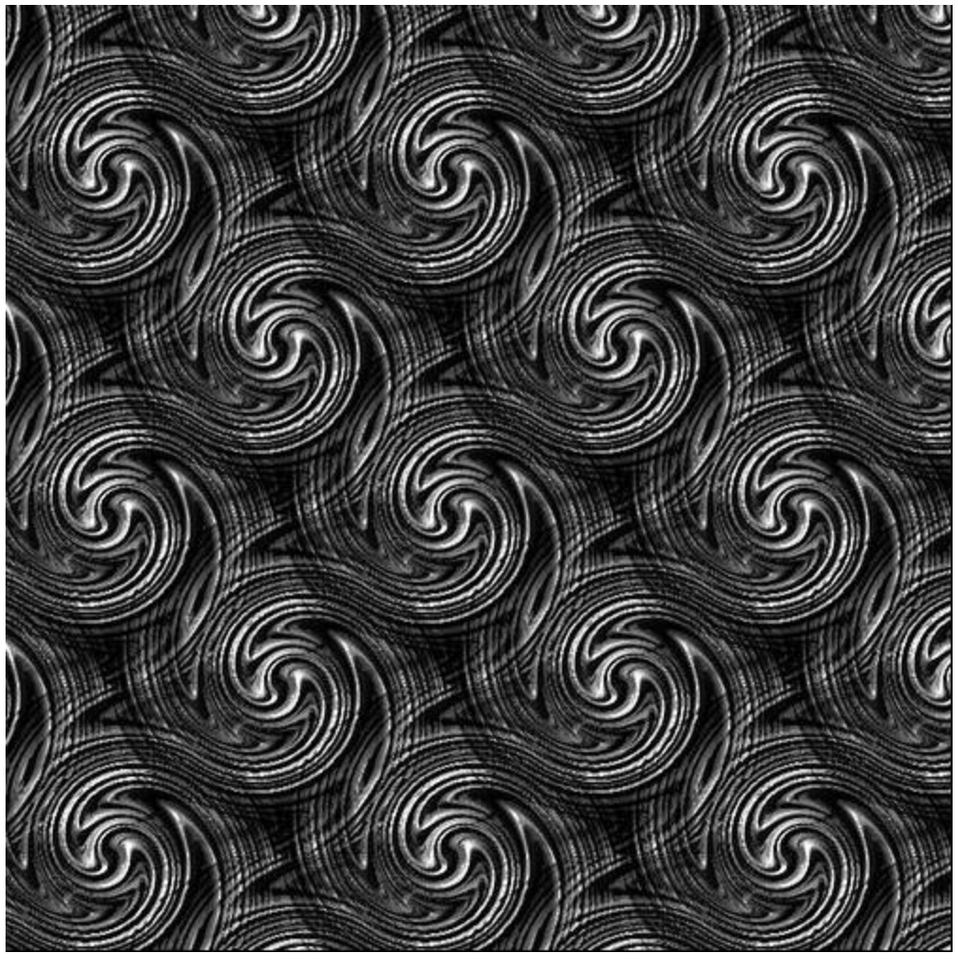
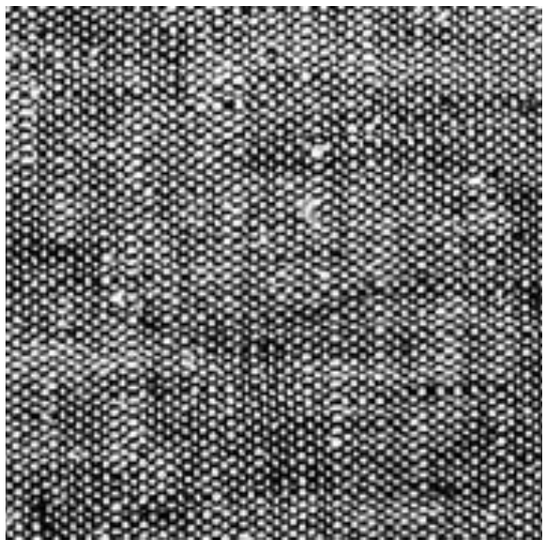


Image quilting by Efros & Freeman

- Texture 2

input image



size: 201 * 177
window size: 31
overlap size: 11

synthesis image

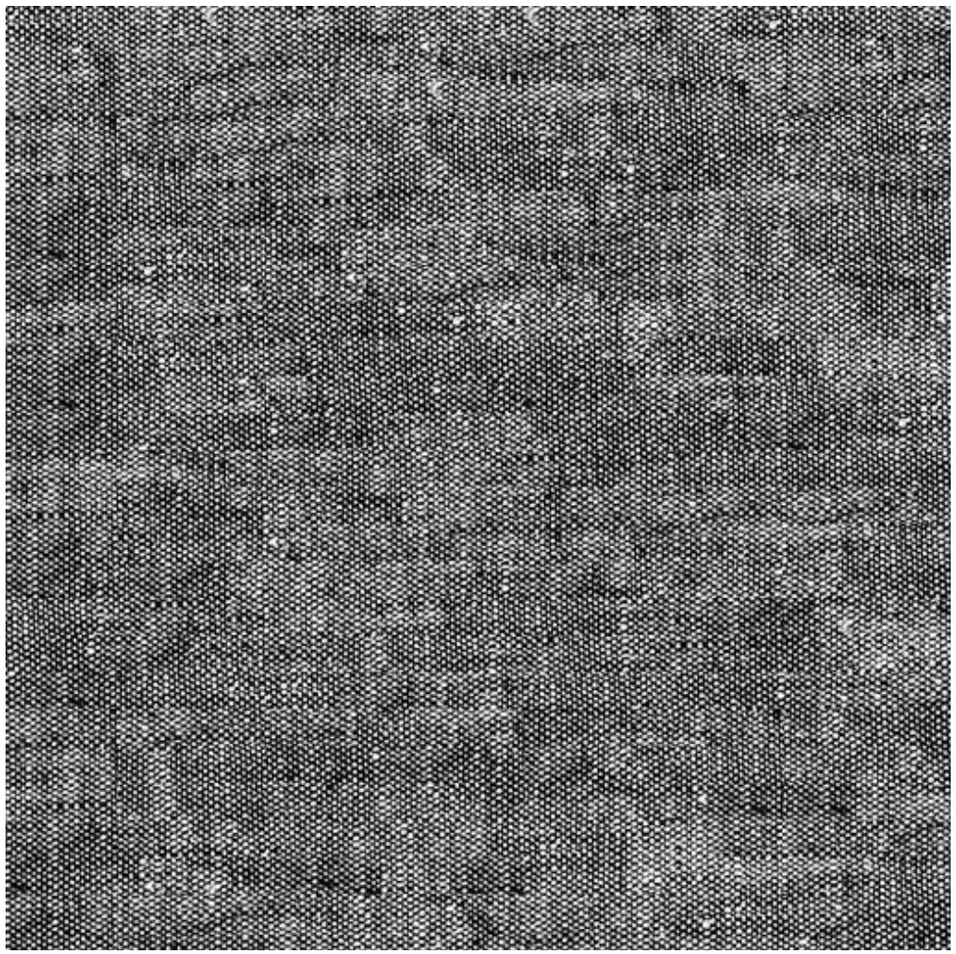


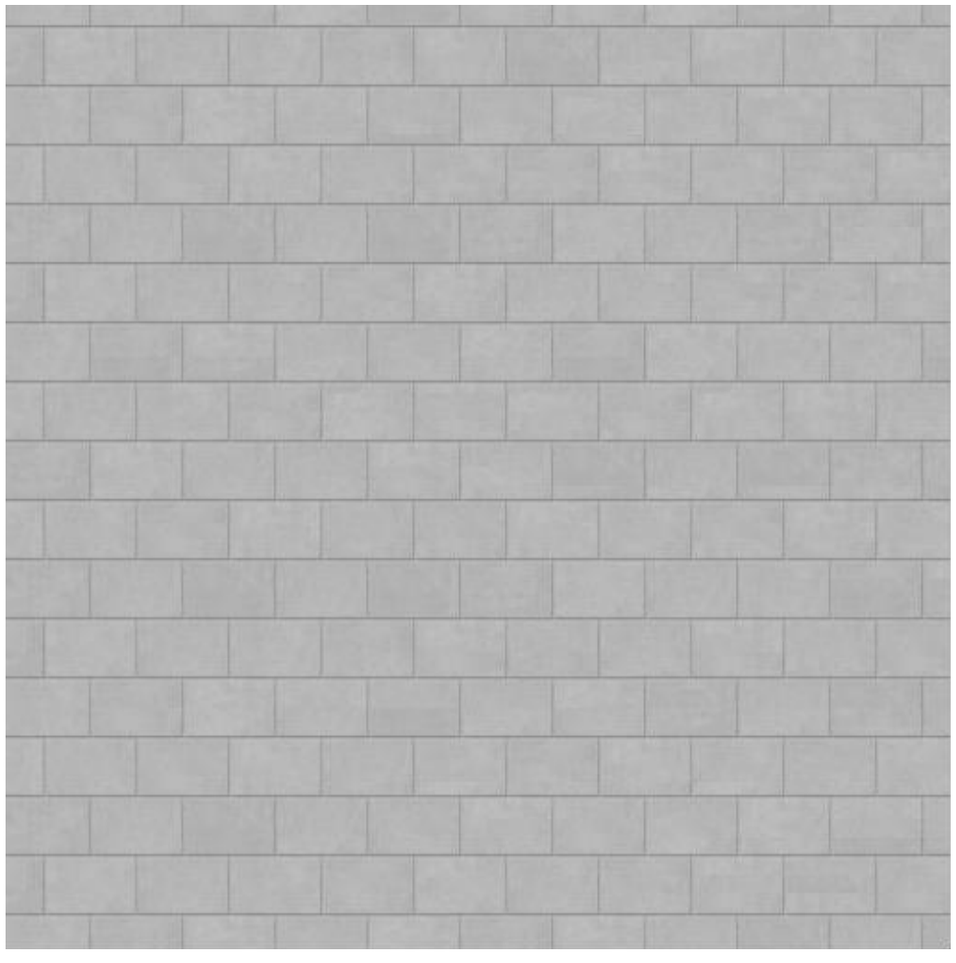
Image quilting by Efros & Freeman

- Texture 3

input image

size: 200 * 200
window size: 31
overlap size: 21

synthesis image



Exchange the type of different textures

input

output

Assignment #3 - Bonus

- Produce an image in Fig. 4 by adopting appropriate morphological processing

Fig. 3: sample 3.raw

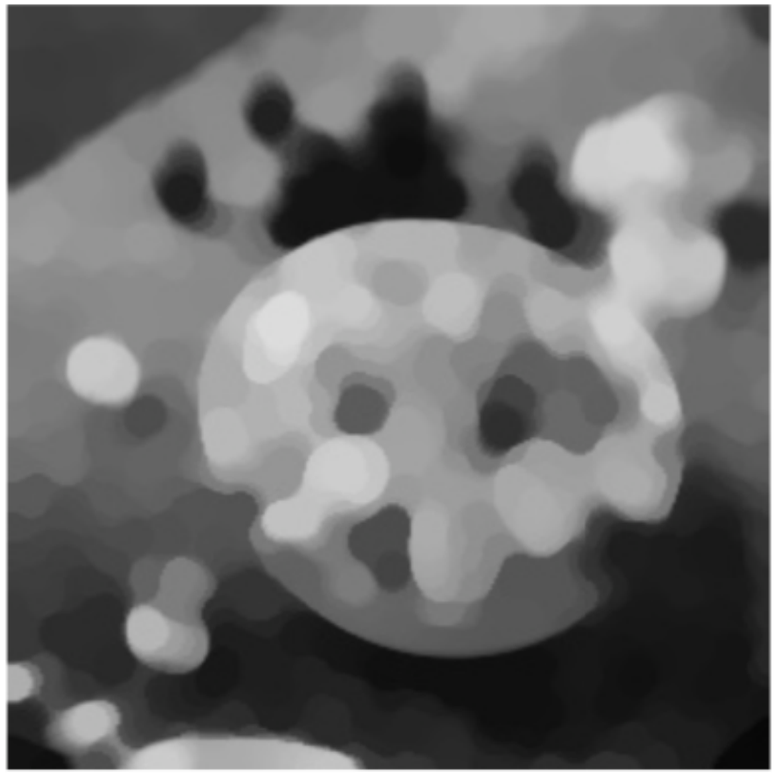


Fig. 4: The desired image

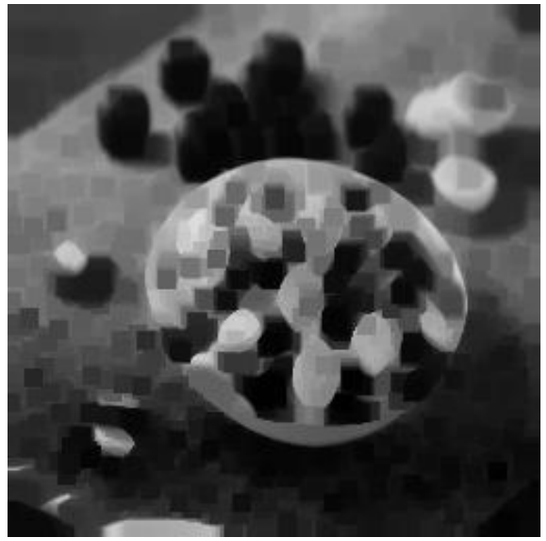
Dilation & Erosion

- Dilation
  - Maximum filter
- Erosion
  - Minimum filter

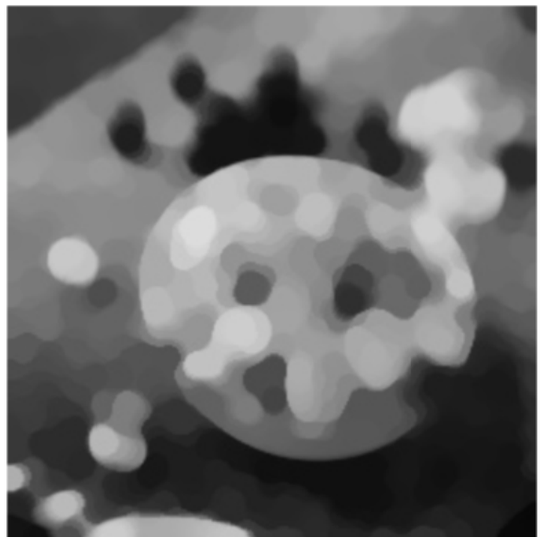
Experiment

- Step I: Erosion (window size = 9)

input

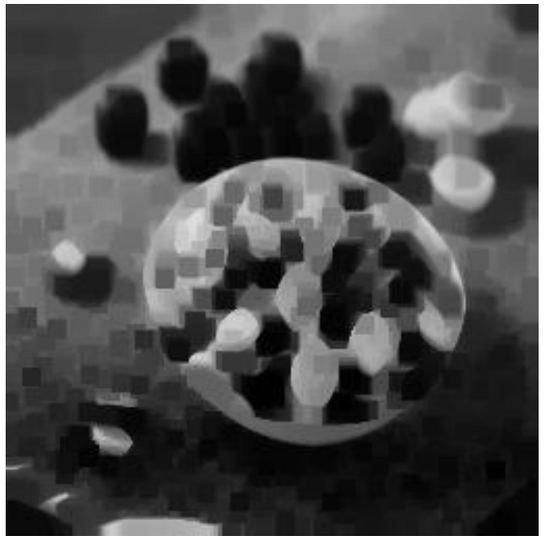


output



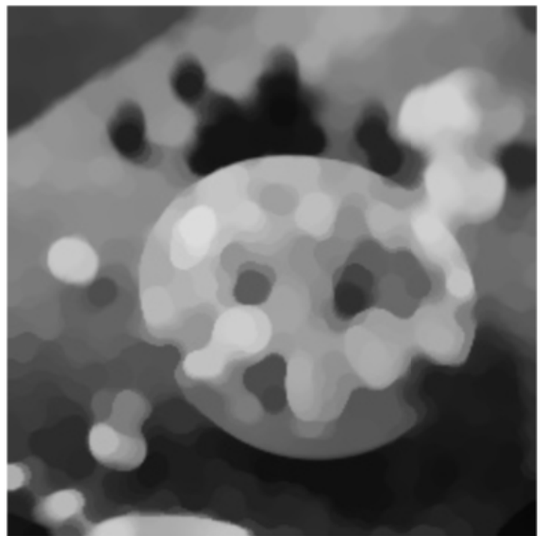
desired image

- Step II: Dilation (window size = 11)



input

output



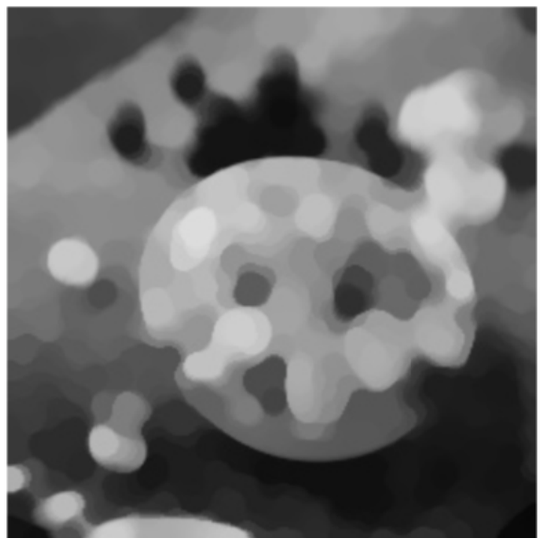
desired image

Experiment

- Step III: Median Filter (window size = 7)

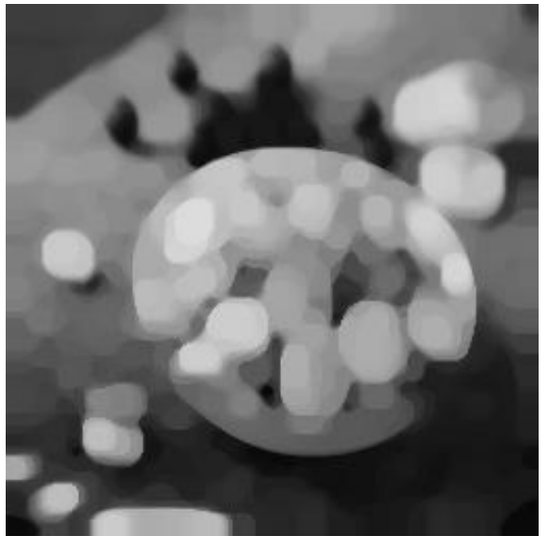
input

output

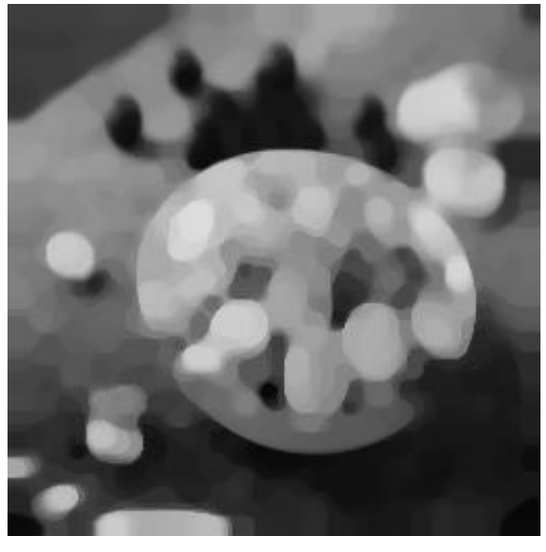


desired image

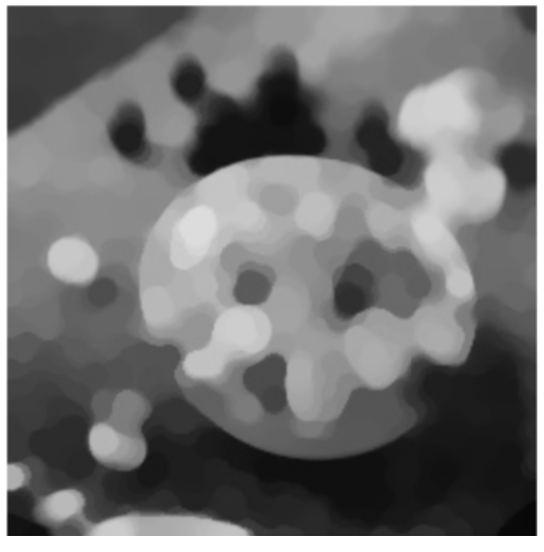
- Step IV: Dilation (window size = 3)



input



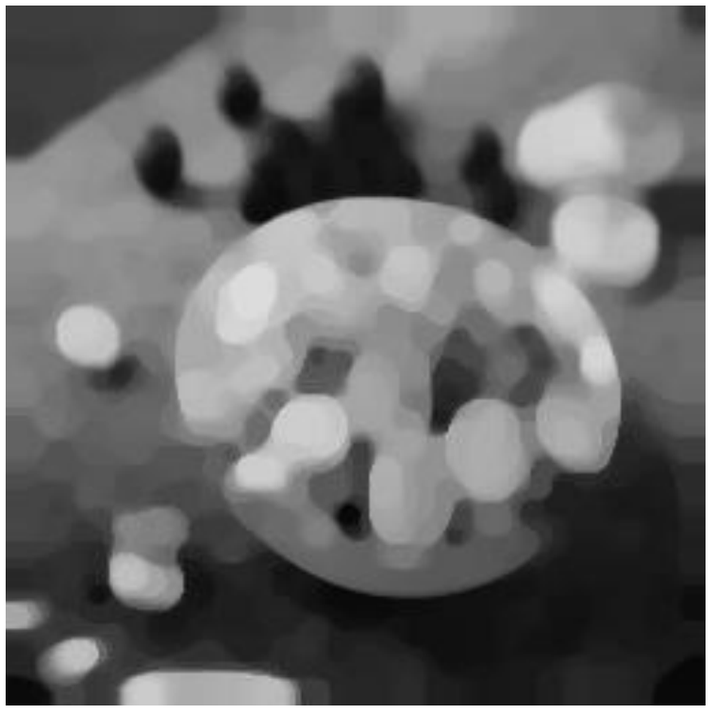
output



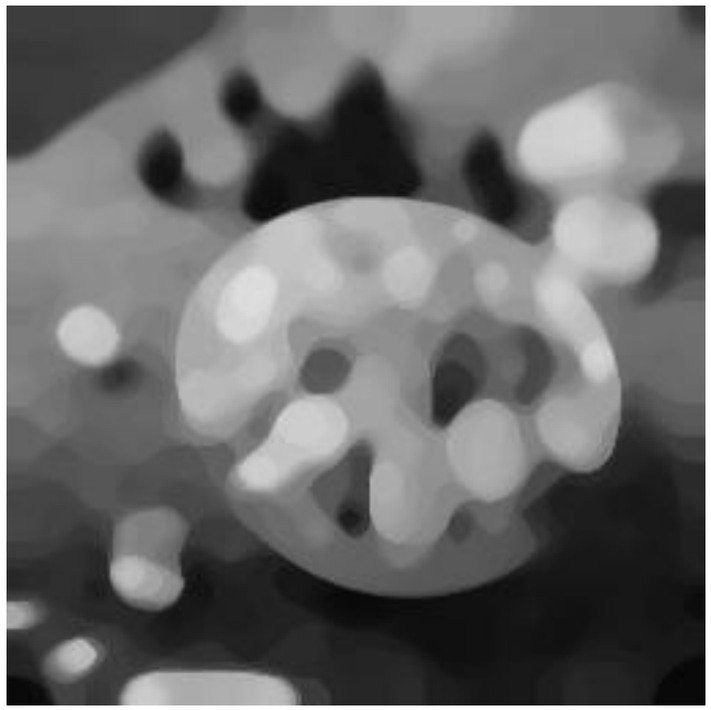
desired image

Experiment

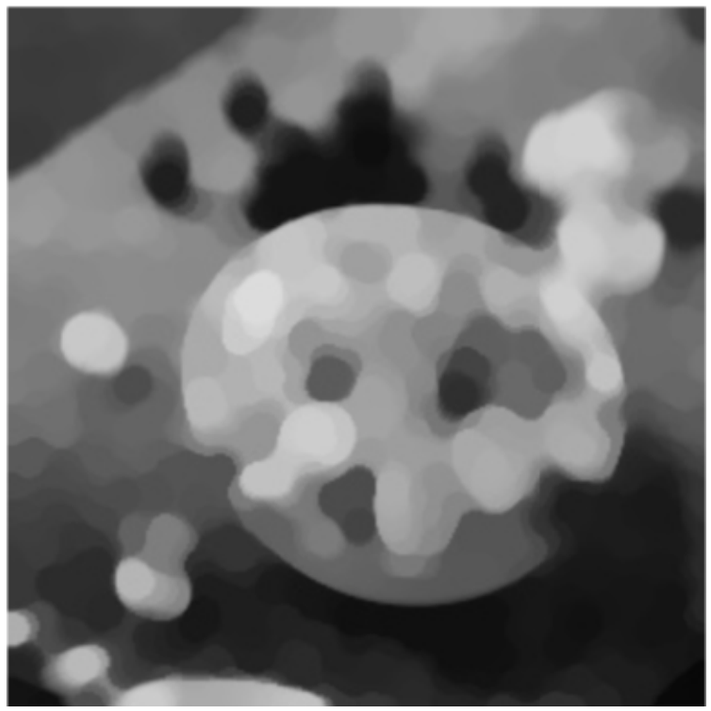
- Step V: Median Filter (window size = 11)



input



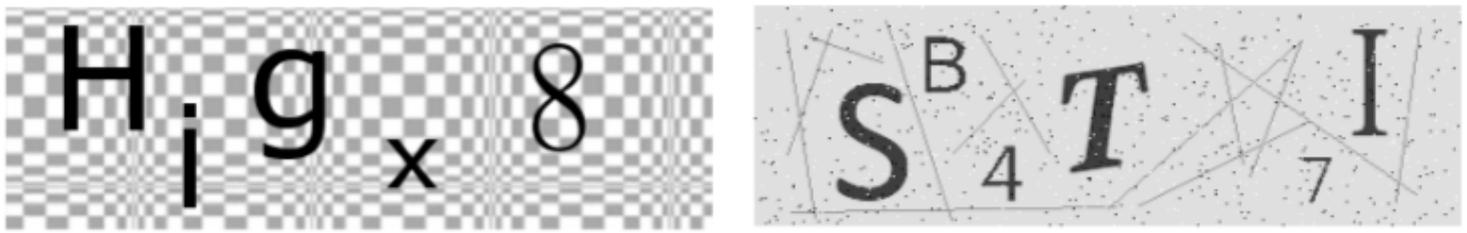
output



desired image

Assignment #4 - problem 1

- Please design an algorithm to recognize the CAPTCHA images as shown in Fig. 1. The training set is given in Fig. 2. Please describe the proposed algorithm in detail along with a flowchart and discuss the recognition results.



(a) sample1.raw (b) sample2.raw

Fig. 1: Two CAPTCHA images

Fig. 2: TrainingSet.raw

Assignment #4 - problem 1

- Please design an algorithm to recognize the CAPTCHA images as shown in Fig. 1. The training set is given in Fig. 2. Please describe the proposed algorithm in detail along with a flowchart and discuss the recognition results.

I. 先將training set和testing set圖中每個字的bounding box找出來
II. 將testing set的字分別和每個training set的字比較
    ① 先比較寬高比：如果相差大於0.2，視為不可能為該字，直接跳過
    ② 將training set的字大小縮放到和testing set相同
    ③ 將testing set的每個pixel和training set對應的pixel值比較
        - 設一個初始分數0，如果兩邊的pixel值相同，分數加一；如果不同，分數減一
III. training set中分數最高的字即為最後的預測結果