Digital Color Image Processing

Computer Exercise

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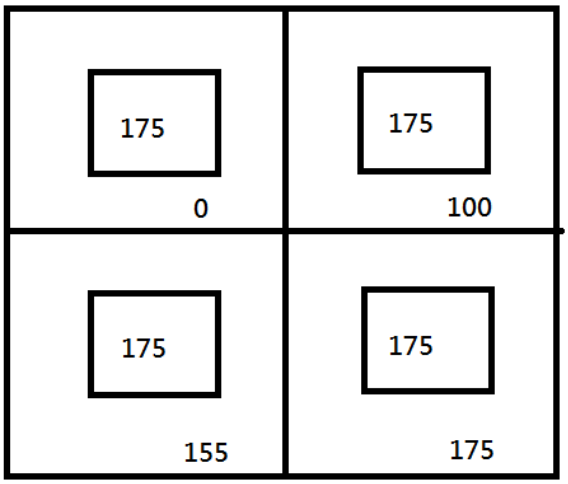
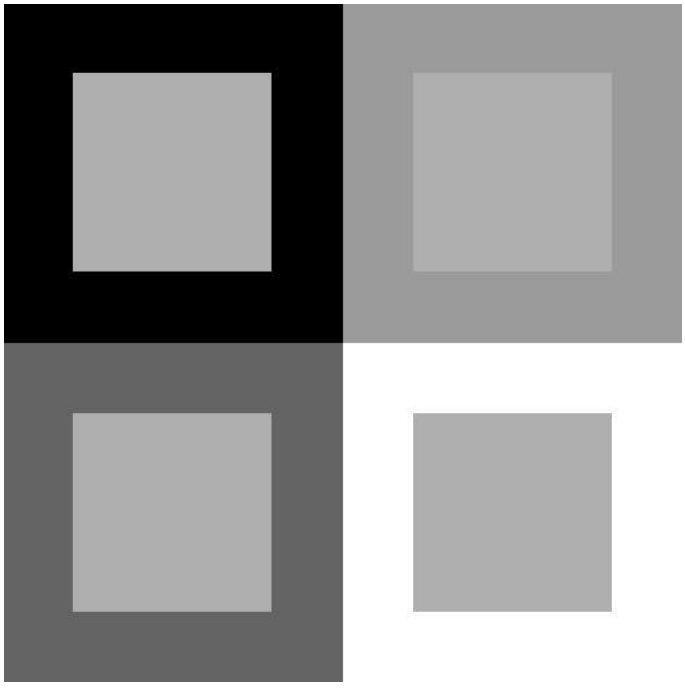
Computer Exercise 1.

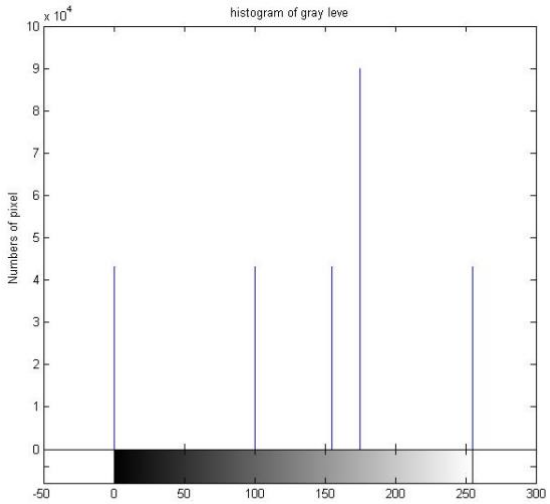
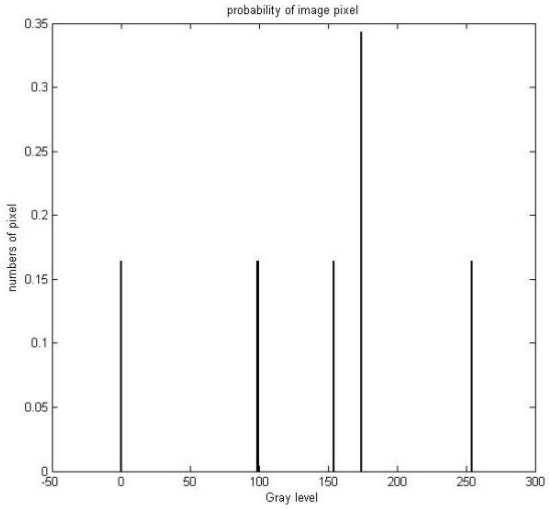
- Simultaneous Contrast

示意圖



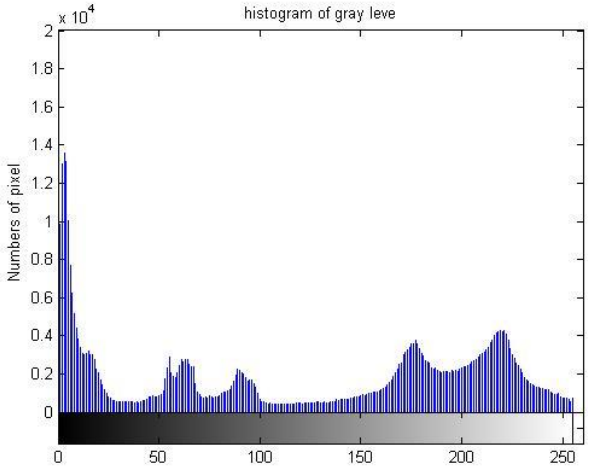
實際圖

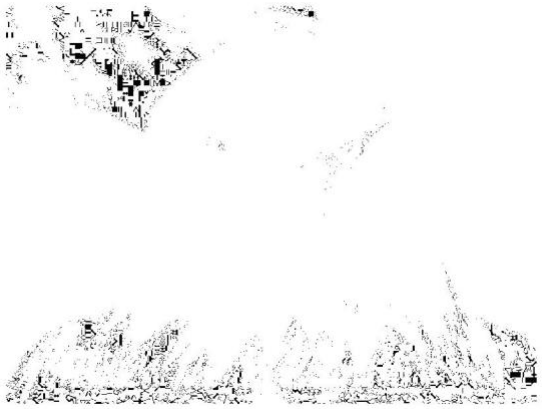


Histogram Plot(Number)	Histogram Plot(Probability)
	

Computer Exercise 2.

- **Histogram Plots of Digital Image & its segemetation**

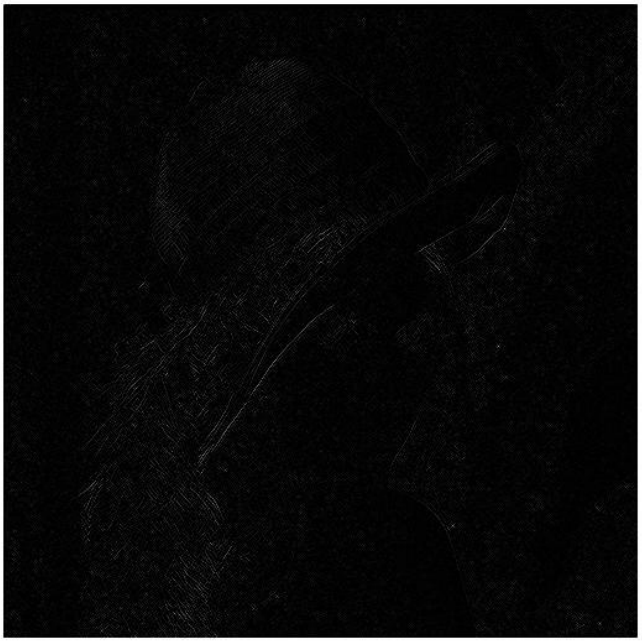
Original Image 800x600 gray image	Corresponding histogram
	

Gray level = 3	Gray level = [1,2,3,4,5]
	
在灰階值 =3 時，可以粗略的老鷹圖像描繪出來。	在灰階值等於[1,2,3,4,5]時，可將更清晰的老鷹圖像，以及部分的美國國旗描繪出來。

Computer Exercise 3.

- **Edge Detection**

Mask1:H = $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$	

Mask2:H = $\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$	
Mask3:H = $\begin{bmatrix} 1 & -2 & -1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$	

Add Edge-Enhanced Image to the Original Image **Mask4:H =** $\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$ + $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$ $= \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$	
Sobel **該算子包含兩組 3x3 的矩陣，分別為橫向及縱向，將之與圖像作平面卷積，即可分別得出橫向及縱向的亮度差分近似值。**	
Discussion	**由上述幾組圖片可以看到，相較於 Sobel 邊緣偵測，單單用一個遮罩進行邊緣偵測的結果(Mask1、2、3)，因為沒有經過梯度的運算，故其結果並不會這麼明顯。**

Computer Exercise 4.

- **Invariant Color Space**

(1) RGB to C space

$$\mathbf{C_1} = tan^{-1}\left(\frac{R}{Max(G,B)}\right)$$

$$\mathbf{C_2} = tan^{-1}\left(\frac{G}{Max(R,B)}\right)$$

$$\mathbf{C_3} = tan^{-1}\left(\frac{B}{Max(R,G)}\right)$$

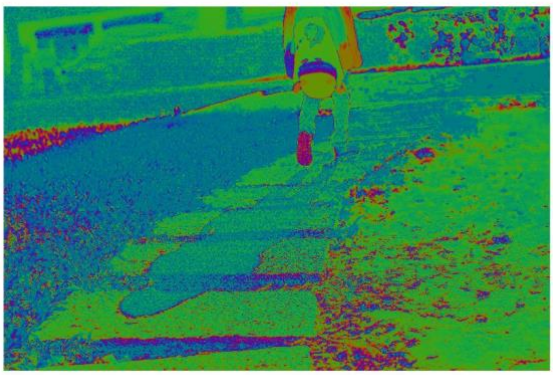
Original	C space
	

(2) RGB to $\mathbf{l_1, l_2, l_3}$ Color Space

$$\mathbf{l_1} = \frac{|\mathbf{R}-\mathbf{G}|}{|\mathbf{R}-\mathbf{G}|+|\mathbf{G}-\mathbf{B}|+|\mathbf{R}-\mathbf{B}|}$$

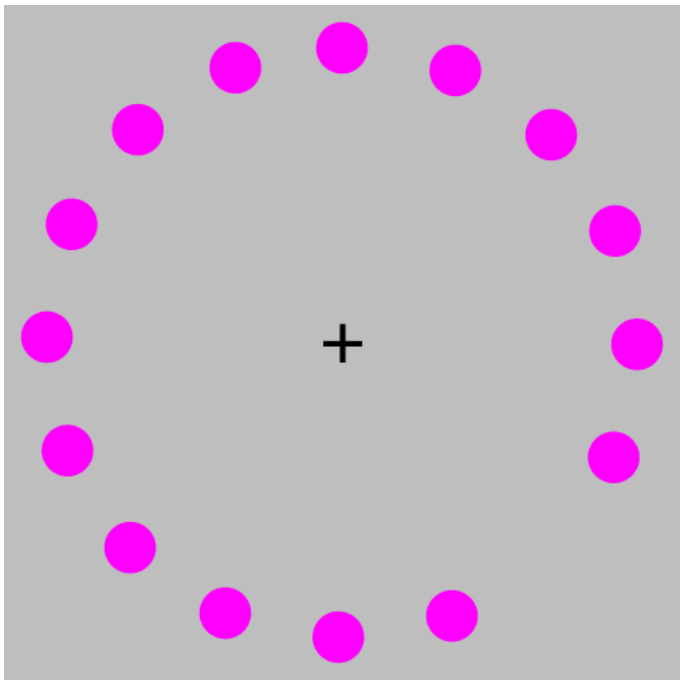
$$\mathbf{l_2} = \frac{|\mathbf{R}-\mathbf{B}|}{|\mathbf{R}-\mathbf{G}|+|\mathbf{G}-\mathbf{B}|+|\mathbf{R}-\mathbf{B}|}$$

$$\mathbf{l_3} = \frac{|\mathbf{B}-\mathbf{G}|}{|\mathbf{R}-\mathbf{G}|+|\mathbf{G}-\mathbf{B}|+|\mathbf{R}-\mathbf{B}|}$$

Original	$\mathbf{l_1, l_2, l_3}$ Color Space
	

Computer Exercise 5.

- **Lilac Chaser**



寫一個程式，使周圍有許多同色的圓形，並有個空缺，並使之旋轉，眼睛盯著中間十字後，在旋轉時，空缺處會產生某色球的互補色。

Lilac Chaser 是一種視覺錯覺，通常會在周圍圓盤上加入模糊的效果，主要產生錯覺的原因為飛現象(phi phenomenon)和視覺暫留所引起的視覺錯覺。

心得➔在盯著十字中心後約莫五秒鐘，就能看到紫紅色的互補色(綠色)在周圍旋轉。

Computer Exercise 6.

- **Color Simultaneous Contrast**

RGB ➔ HSV ➔RGB

simple:

RGB to HSV Convertion Formular

R' = R/255

G' = G/255

B' = B/255

Cmax = max(R', G', B')

Cmin = min(R', G', B')

Δ = Cmax - Cmin

Hue calculation:

$$H = \begin{cases} 0^\circ & \Delta = 0 \\ 60^\circ \times \left(\frac{G'-B'}{\Delta} mod 6\right) & , C_{max} = R' \\ 60^\circ \times \left(\frac{B'-R'}{\Delta} + 2\right) & , C_{max} = G' \\ 60^\circ \times \left(\frac{R'-G'}{\Delta} + 4\right) & , C_{max} = B' \end{cases}$$

Saturation calculation:

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases}$$

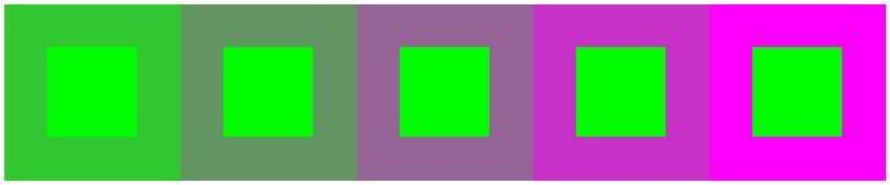
Value calculation:

V = Cmax

➔在此 Color Space 的互補色可在 RGB Color Space 很快求出

➔(R,G,B) 的互補色為(255-R,255-G,255-B)

- ✓ **Final Result**

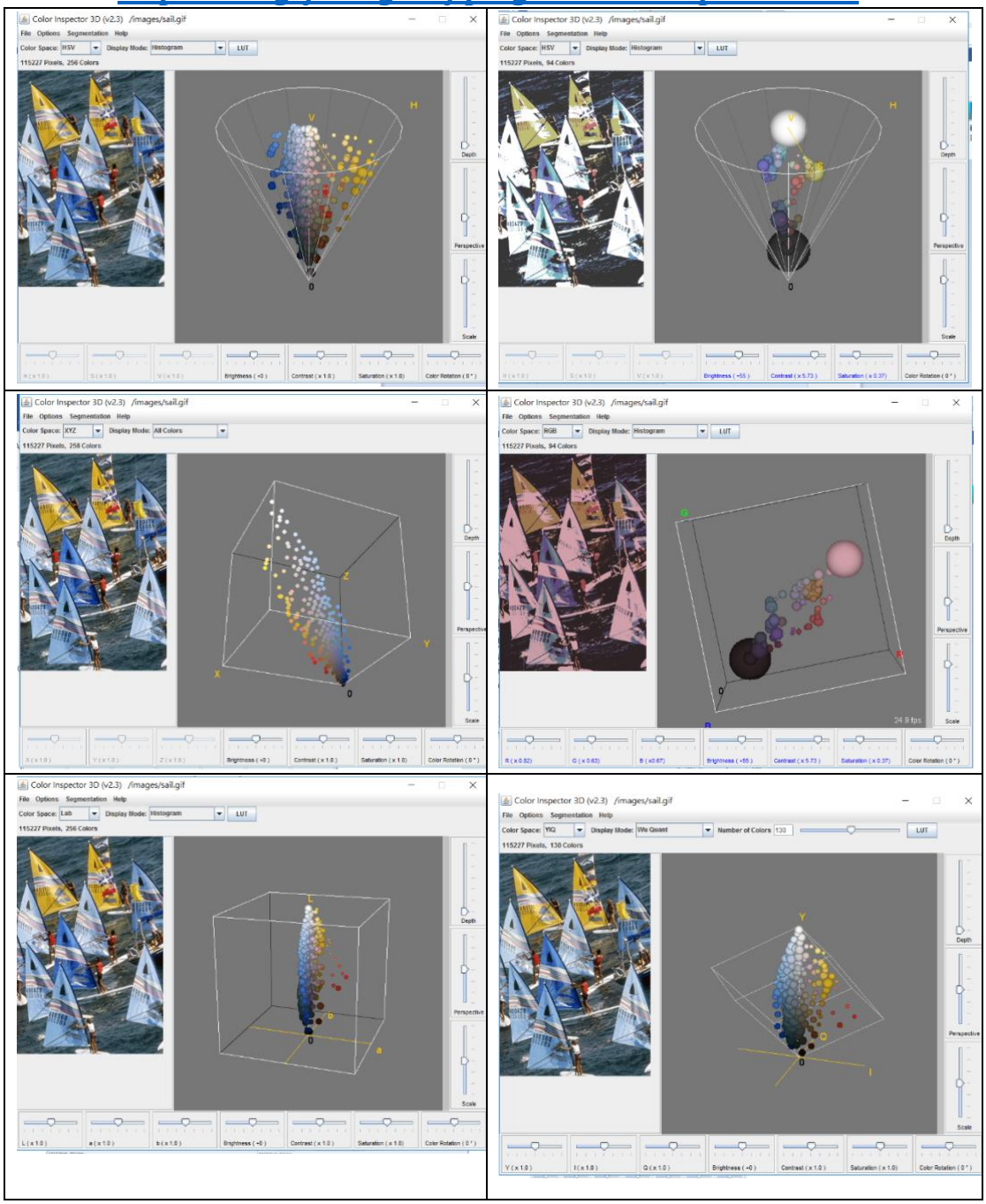


- **由上圖可以看到，影像對比的增強變化，固定住中間的方塊皆為綠色 (0,255,0)，可以發現有左至右，RGB 分別為(50,200,50)、(100,150,100)、(150,100,150)、(200,50,200)、(255,0,255)，顏色的對比越來越明顯。**

Computer Exercise 7

- **Color Mapping using 3-D Color Inspector/Color histogram**

Source: https://imagej.nih.gov/ij/plugins/color-inspector.html



- 此 Color Inspector 是由 java 寫成的，可以讀入不同的圖片，並在不同的色彩空間對於色彩的長條圖進行拉伸，藉此觀察圖片的變化情形，或者在每種色彩空間，都可以對於圖片的 HSV 進行調整。在長條圖或立方體或圓錐等等的不同色彩空間立體表示，觀察圖片的變化。

Computer Exercise 8.

Image Warpping

$$x' = (x - c_x)\cos\theta + (y - c_y)\sin\theta + c_x$$
$$y' = -(y - c_y)\sin\theta + (y - c_y)\cos\theta + c_y$$

(Cx,Cy) is the rotation center

ssd = $\theta = \frac{r}{2}$

in matrix form

$$\begin{bmatrix} x' - Cx \\ y' - Cy \end{bmatrix} = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} x - Cx \\ y - Cy \end{bmatrix}$$

➔直接投影會產生空隙，如圖

➔故反過來 mapping，就不會有點空隙

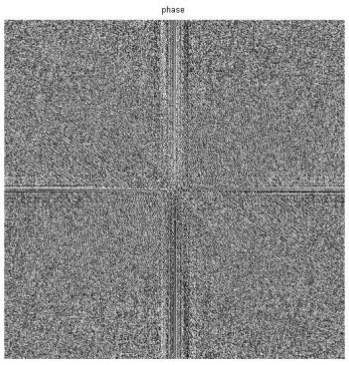
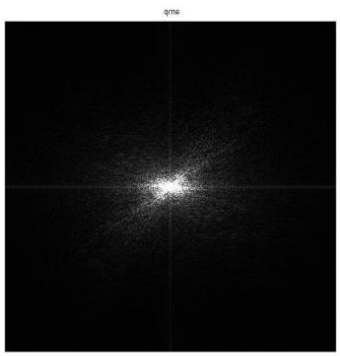
➔The Result of Lena

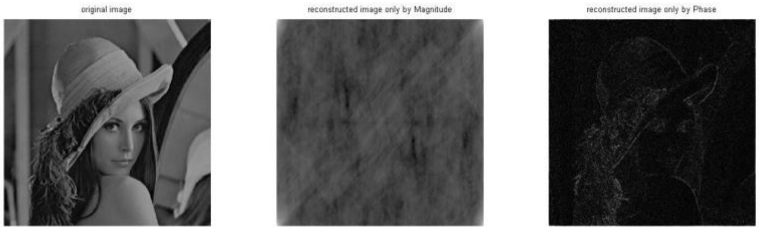
➔此兩張圖除了有無空隙外，扭曲的結果也不一樣，主要原因為解析度不同所造成，Result 是以 512x512 的解析度，而上圖是以 256x256 的解析度進行投影。

Ref : Slabaugh, Greg, Richard Boyes, and Xiaoyun Yang. "Multicore image processing with openmp [applications corner]." *IEEE Signal Processing Magazine* 27.2 (2010): 134-138.

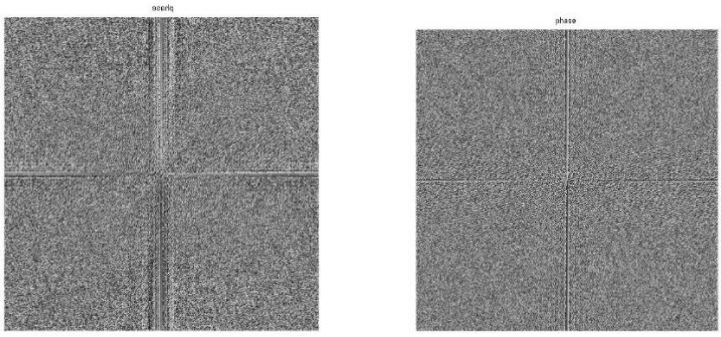
Computer Exercise 9.

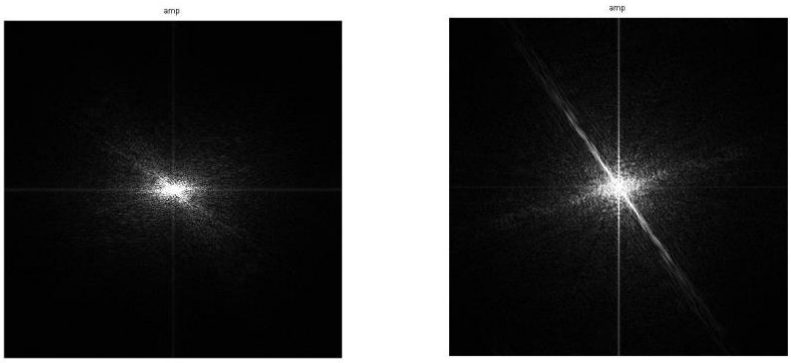
1.Do 2DFFT & IFFT of Lena image.求得 Amplitude only & phase only image

Origial Image	
Phase & Amplitude	 

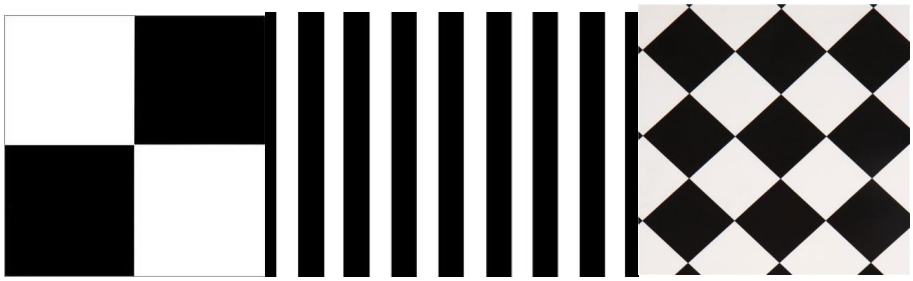
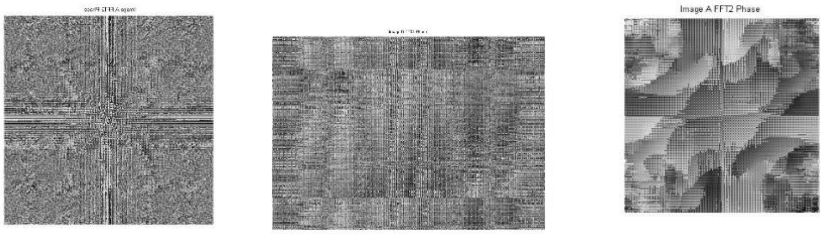
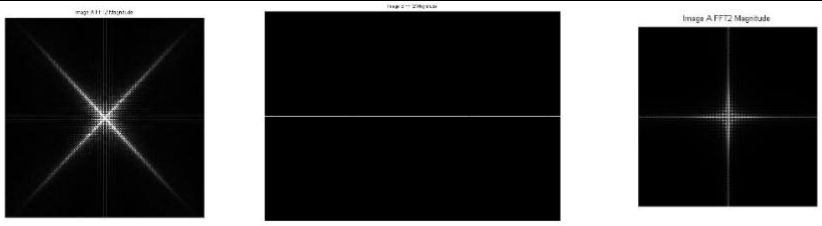
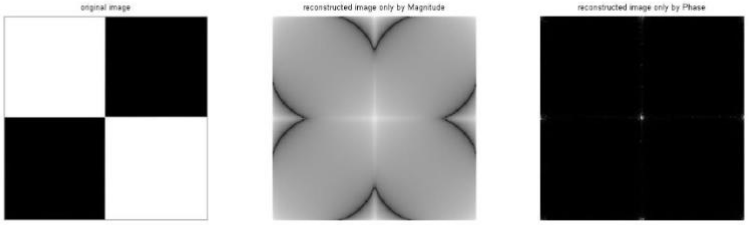
2DIFFT	
● **在 IFFT(phase)中還依稀看得出原圖，而在 IFFT(Amplitude)則是完全看不出來，故在圖 phase 較 amp 重要。**	

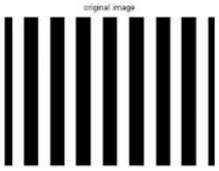
2.IFFT(One image(Lena) + another image)

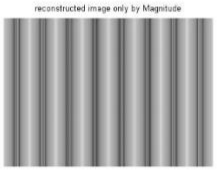
Original image	
Phase **left:lena** **right:man**	

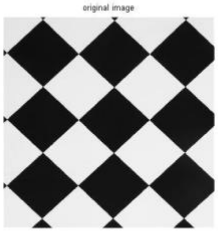
Amplitude **left:Lena** **right:Man**	
Lena's Phase **+** **Man's Amplitude**	
Lena's Amplitude **+** **Man's Phase**	
● **不論是哪張圖片，因為 Phase 的資訊較為重要，故只要有採用該張圖片的 Phase 加另一圖片的 Amplitude，結果會呈現出 Phase 為主的原圖資訊。**	

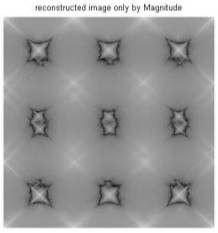
3.When the image is stripe lines or checker board , the amp. is more important than phase info.

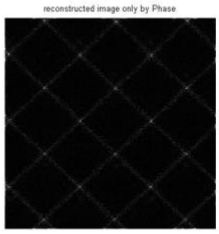
Origial image	
Phase	
Amp.	
The Result	







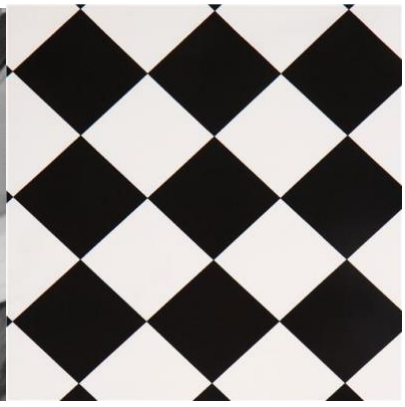


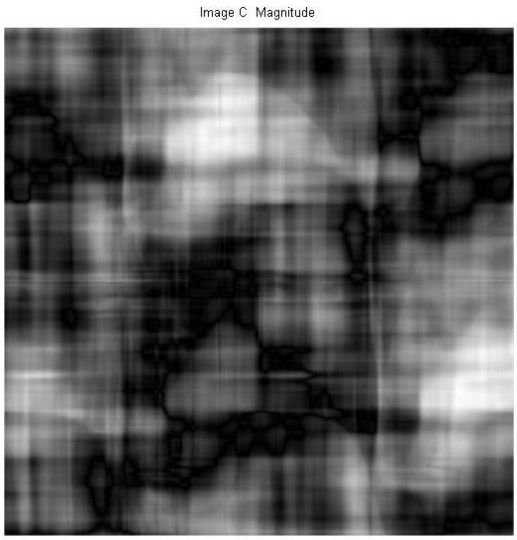


- **在上述例子，amp info is more important than phase info.，原因為高頻的成分較多，所以 amp 較重要。**

4.Lena's phase + Stripe's (or square)Amplitude.

➔Lena 出不來

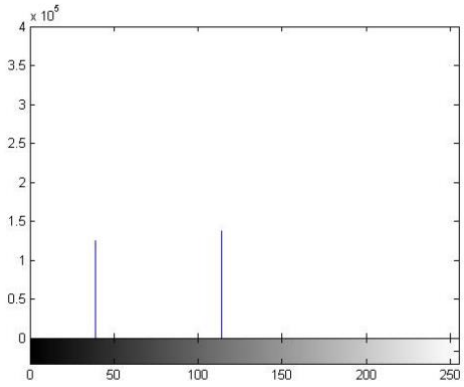
Original Image	 

Lena's Phase + Square's amp	
● **在上圖還稍微看的到 Lena 的輪廓，如欲使影像更清晰，可用 Lena 的影像只給 Phase ➔2DFFT➔Phase + Amp ➔2D IFFT，此方法進行疊代，，利用 phase 重建影像。**	

Computer Exercise 10.

1.Do computer program for multilevel threshold for Lena's Image(256 Gray level ➔ 2,3,4 levels). Plot Histogram & Threshold

2 levels & Histogram **Z0 = 39** **Z1 = 114** **P0 = 0.4793** **P1 = 0.5207** **Threshold = 79**	**Solution** A.*1. Bilevel Thresholding Solutions* (i) $c_d = \begin{vmatrix} m_0 & m_1 \\ m_1 & m_2 \end{vmatrix}$; $c_0 = (1/c_d)\begin{vmatrix} -m_2 & m_1 \\ -m_3 & m_2 \end{vmatrix}$; $c_1 = (1/c_d)\begin{vmatrix} m_0 & -m_2 \\ m_1 & -m_3 \end{vmatrix}$. (ii) $z_0 = (\tfrac{1}{2})\left[-c_1 - (c_1^2 - 4c_0)^{1/2}\right]$; $z_1 = (\tfrac{1}{2})\left[-c_1 + (c_1^2 - 4c_0)^{1/2}\right]$. (iii) $p_d = \begin{vmatrix} 1 & 1 \\ z_0 & z_1 \end{vmatrix}$; $p_0 = (1/p_d)\begin{vmatrix} 1 & 1 \\ m_1 & z_1 \end{vmatrix}$; $p_1 = 1 - p_0$.



3 levels & Histogram

Z0 = 24

Z1 = 82

Z2 = 134

P0 = 0.2523

P1 = 0.5414

P2 = 0.2063

Threshold

t1 = 50

t2 = 107

Solution

A.2. *Trilevel Thresholding Solutions*

(i)

$$c_d = \begin{vmatrix} m_0 & m_1 & m_2 \\ m_1 & m_2 & m_3 \\ m_2 & m_3 & m_4 \end{vmatrix};$$

$$c_0 = (1/c_d)\begin{vmatrix} -m_3 & m_1 & m_2 \\ -m_4 & m_2 & m_3 \\ -m_5 & m_3 & m_4 \end{vmatrix};$$

$$c_1 = (1/c_d)\begin{vmatrix} m_0 & -m_3 & m_2 \\ m_1 & -m_4 & m_3 \\ m_2 & -m_5 & m_4 \end{vmatrix};$$

$$c_2 = (1/c_d)\begin{vmatrix} m_0 & m_1 & -m_3 \\ m_1 & m_2 & -m_4 \\ m_2 & m_3 & -m_5 \end{vmatrix}.$$

(ii)

$$z_0 = -c_2/3 - A - B;$$
$$z_1 = -c_2/3 - W_1A - W_2B;$$
$$z_2 = -c_2/3 - W_2A - W_1B,$$

where A, B, W_1, and W_2 are as follows:

$$A = \left\{(c_0/2 - c_1c_2/6 + c_2^3/27) - \left[(c_0/2 - c_1c_2/6 + c_2^3/27)^2 + (c_1/3 - c_2^2/9)^3\right]^{1/2}\right\}^{1/3};$$

$$B = -(c_1/3 - c_2^2/9)/A;$$
$$W_1 = -1/2 + i(\sqrt{3}/2);$$
$$W_2 = -1/2 - i(\sqrt{3}/2);$$
$$i = \sqrt{-1}.$$

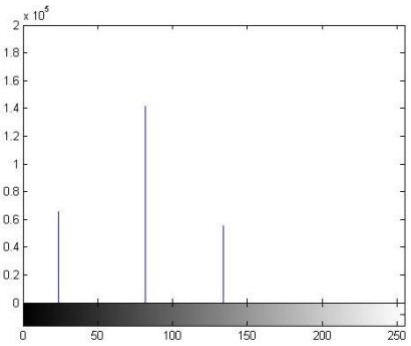
(iii)

$$p_d = \begin{vmatrix} 1 & 1 & 1 \\ z_0 & z_1 & z_2 \\ z_0^2 & z_1^2 & z_2^2 \end{vmatrix};$$

$$p_0 = (1/p_d)\begin{vmatrix} m_0 & 1 & 1 \\ m_1 & z_1 & z_2 \\ m_2 & z_1^2 & z_2^2 \end{vmatrix};$$

$$p_1 = (1/p_d)\begin{vmatrix} 1 & m_0 & 1 \\ z_0 & m_1 & z_2 \\ z_0^2 & m_2 & z_2^2 \end{vmatrix};$$

$$p_2 = 1 - p_0 - p_1.$$



4level & Histogram

Z0 = 18

Z1 = 57

Z2 = 101

Z3 = 142

P0 = 0.1709

P1 = 0.3213

P2 = 0.3986

P3 = 0.1091

Threshold

t1 = 32

t2 = 80

t3 = 125

A.3. *Quaterlevel Thresholding Solutions*

(i)

$$c_d = \begin{vmatrix} m_0 & m_1 & m_2 & m_3 \\ m_1 & m_2 & m_3 & m_4 \\ m_2 & m_3 & m_4 & m_5 \\ m_3 & m_4 & m_5 & m_6 \end{vmatrix};$$

$$c_0 = (1/c_d)\begin{vmatrix} -m_4 & m_1 & m_2 & m_3 \\ -m_5 & m_2 & m_3 & m_4 \\ -m_6 & m_3 & m_4 & m_5 \\ -m_7 & m_4 & m_5 & m_6 \end{vmatrix};$$

$$c_1 = (1/c_d)\begin{vmatrix} m_0 & -m_4 & m_2 & m_3 \\ m_1 & -m_5 & m_3 & m_4 \\ m_2 & -m_6 & m_4 & m_5 \\ m_3 & -m_7 & m_5 & m_6 \end{vmatrix};$$

$$c_2 = (1/c_d)\begin{vmatrix} m_0 & m_1 & -m_4 & m_3 \\ m_1 & m_2 & -m_5 & m_4 \\ m_2 & m_3 & -m_6 & m_5 \\ m_3 & m_4 & -m_7 & m_6 \end{vmatrix};$$

$$c_3 = (1/c_d)\begin{vmatrix} m_0 & m_1 & m_2 & -m_4 \\ m_1 & m_2 & m_3 & -m_5 \\ m_2 & m_3 & m_4 & -m_6 \\ m_3 & m_4 & m_5 & -m_7 \end{vmatrix}.$$

(ii)

$$z_0 = (\tfrac{1}{2})\{-(c_3/2 + A) - [(c_3/2 + A)^2 - 4(Y + B)]^{1/2}\};$$

$$z_1 = (\tfrac{1}{2})\{-(c_3/2 + A) + [(c_3/2 + A)^2 - 4(Y + B)]^{1/2}\};$$

$$z_2 = (\tfrac{1}{2})\{-(c_3/2 - A) - [(c_3/2 - A)^2 - 4(Y - B)]^{1/2}\},$$

$$z_3 = (\tfrac{1}{2})\{-(c_3/2 - A) + [(c_3/2 - A)^2 - 4(Y - B)]^{1/2}\}.$$

$$A = \left(\tfrac{1}{2}\right)\left(c_3^2 - 4c_2 + 8Y\right)^{1/2};$$

$$\mathbf{B} = (\mathbf{c3Y} - \mathbf{c1})/\mathbf{2A}$$

$$\mathbf{C} = [\mathbf{G} - (\boldsymbol{G^2} + \boldsymbol{H^3})^{\mathbf{1/2}}]^{\frac{\mathbf{1}}{\mathbf{3}}}$$

$$D = -H/C;$$

$$G = \left(\tfrac{1}{432}\right)\left(72c_0c_2 + 9c_1c_2c_3 - 27c_1^2 - 27c_0c_3^2 - 2c_2^3\right);$$

$$H = \left(\tfrac{1}{36}\right)\left(3c_1c_3 - 12c_0 - c_2^2\right).$$

(iii)

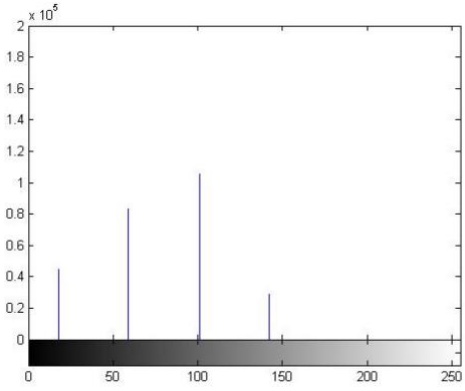
$$p_d = \begin{vmatrix} 1 & 1 & 1 & 1 \\ z_0 & z_1 & z_2 & z_3 \\ z_0^2 & z_1^2 & z_2^2 & z_3^2 \\ z_0^3 & z_1^3 & z_2^3 & z_3^3 \end{vmatrix};$$

$$p_0 = (1/p_d)\begin{vmatrix} 1 & 1 & 1 & 1 \\ m_1 & z_1 & z_2 & z_3 \\ m_2 & z_1^2 & z_2^2 & z_3^2 \\ m_3 & z_1^3 & z_2^3 & z_3^3 \end{vmatrix};$$

$$p_1 = (1/p_d)\begin{vmatrix} 1 & 1 & 1 & 1 \\ z_0 & m_1 & z_2 & z_3 \\ z_0^2 & m_2 & z_2^2 & z_3^2 \\ z_0^3 & m_3 & z_2^3 & z_3^3 \end{vmatrix};$$

$$p_2 = (1/p_d)\begin{vmatrix} 1 & 1 & 1 & 1 \\ z_0 & z_1 & m_1 & z_3 \\ z_0^2 & z_1^2 & m_2 & z_3^2 \\ z_0^3 & z_1^3 & m_3 & z_3^3 \end{vmatrix};$$

$$p_3 = 1 - p_0 - p_1 - p_2.$$



2.Illustrate the above example's answer.

- **Bilevel**

如圖

Z0 = 12.2698 , Z1 = 37.6060 ➔四捨五入取最接近值 Z0 = 12 ,Z1 = 38

P0 = 0.4984 , P1 = 0.5016

故取 t = 27 結果如下:

```
I =

    12    12    12    12    12    12    38    38    38    38    38    38
    12    12    12    12    12    12    38    38    38    38    38    38
    12    12    12    12    12    12    38    38    38    38    38    38
    12    12    12    12    12    12    38    38    38    38    38    38
```

- **Trilevel**

如圖

Z0 = 10.0405 , Z1 = 25.0021 , Z2 = 39.8442

➔四捨五入取 Z0 = 10 , Z1= 25 ,Z2 = 40

P0 = 0.3607 , P1 = 0.2773 ,P2 = 0.3620

故取 t1 = 18 , t2 = 30

```
I =

    10    10    10    10    25    25    40    25    40    40    40    40
    10    10    10    10    25    25    25    25    40    40    40    40
    10    10    10    10    25    25    25    25    40    40    40    40
    10    10    10    10    25    25    40    25    40    40    40    40
```

- **Quaterlevel**

如圖

Z0 = 9.5171 , Z1 = 19.3371 , Z2 = 30.9802 ,Z3 = 40.4078

➔四捨五入取 Z0 = 10 , Z1= 19 ,Z2 = 31 , Z3 = 40

P0 = 0.3109 , P1 = 0.1912 ,P2 = 0.1903 ,P3 = 0.3075

故取 t1 = 11 , t2 = 27 ,t3 = 37

```
I =

    10    10    10    10    19    19    31    31    40    40    40    40
    19    10    10    10    19    19    31    31    40    40    40    40
    10    10    10    10    19    19    31    31    40    40    40    40
    10    10    10    10    19    19    31    31    40    40    40    40
```