暑期課程　基本影像處理

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Introduction

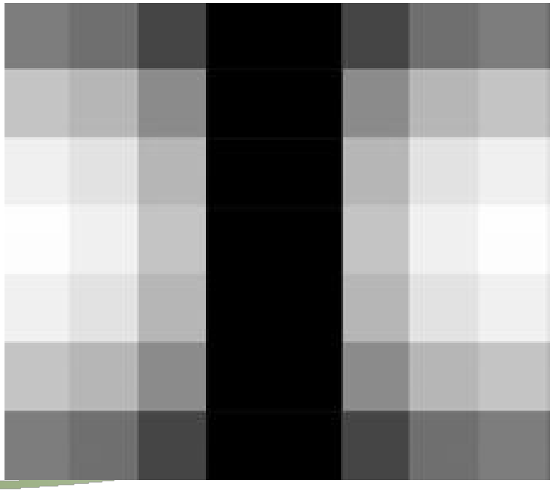
- Filter
  - Sobel (一階導函數應用)
  - Laplacian (二階導函數應用)
- 特性
  - 可計算每一點之梯度值，決定那些點是邊界點
- 用途
  - Edge Detection 邊緣偵測

Edge

What is Edge?

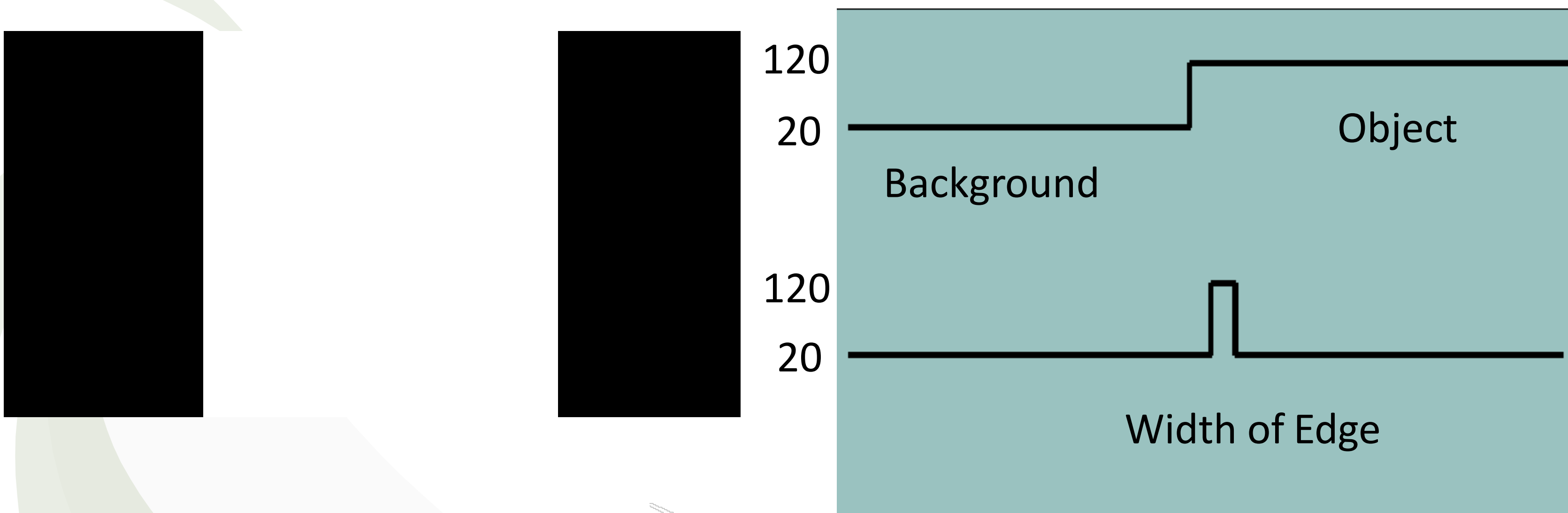
- 邊界點：影像中區隔物體(前景)與背景的點
- 邊界點是用來辨識物體形狀或結構的諸多特徵之一
- 邊界點對後續之位置偵測、特徵抽取、及運動分析也相當重要
- 邊界(edge) ：存在於兩區域間之邊界的連接像數的集合
- Edge Detection 的目的就是將邊界點搜尋出來

  (影像中灰階突然改變的地方)



理論上的邊界

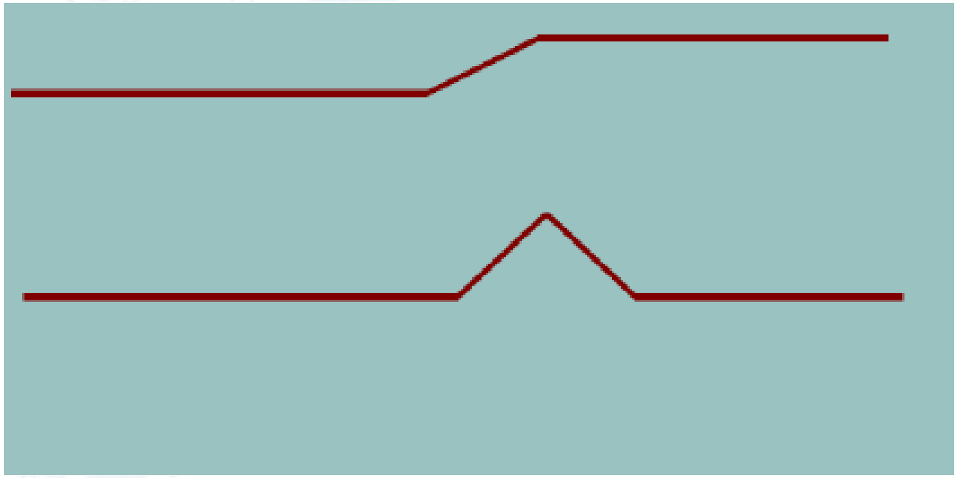
- 理論上邊界處之灰階會呈現階梯狀變化(step edge)或直線狀變化(line edge)。
- 階梯狀邊界代表物體與背景的分界線
- 直線狀邊界代表影像中具有寬度的線



實際上的邊界

- 實際上的影像由於受到雜訊的影響，其邊界形狀並不會是階梯狀或線寬狀，而會變成斜坡狀的邊(ramp edge）或屋頂狀的邊(roof edge)

斜坡狀



Edge Detection

- 搜尋邊界點的方法相當多
  - 型態處理與XOR運算法
  - 梯度運算子
  - 鏈碼輪廓追蹤法　　　　etc

- 要找灰階變化最恰當的工具是 gradient（梯度）

- 一維一階導數

$$f'(x)=\lim_{\triangle x\to 0}\frac{f(x+\triangle x)-f(x)}{\triangle x}=\frac{f(x+1)-f(x)}{1}=f(x+1)-f(x)$$

- 一維二階導數

$$f''(x)$$

$$=(f'(x))'$$

$$=[f(x+1)-f(x)]-[f(x)-f(x-1)]$$

$$=f(x+1)-2f(x)+f(x-1)$$

a b
c

FIGURE 3.38
(a) A simple image. (b) 1-D horizontal gray-level profile along the center of the image and including the isolated noise point.
(c) Simplified profile (the points are joined by dashed lines to simplify interpretation).

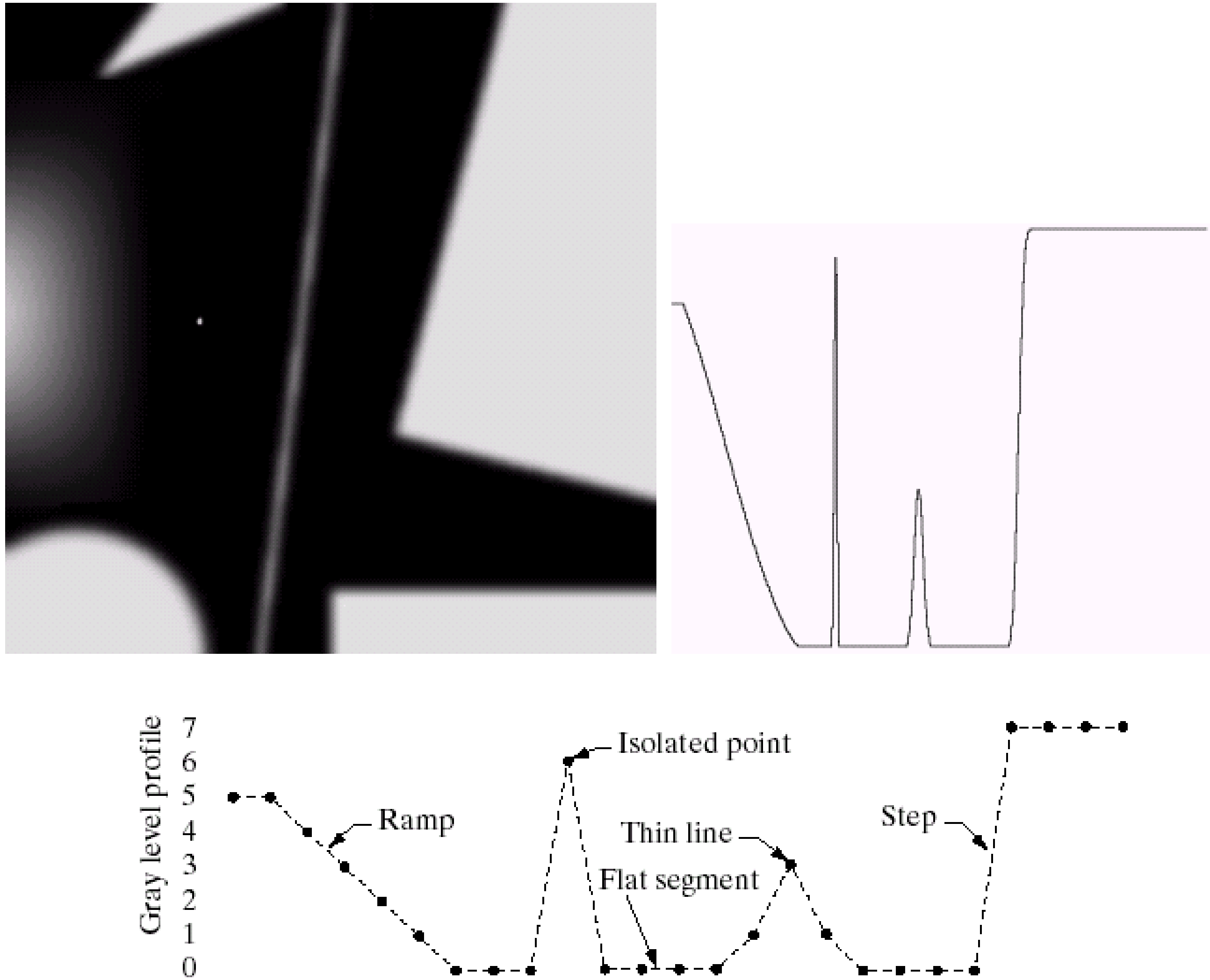


Image strip	5	5	4	3	2	1	0	0	0	6	0	0	0	0	1	3	1	0	0	0	0	7	7	7	7	•	•
First Derivative		−1	−1	−1	−1	−1	0	0	6	−6	0	0	0	1	2	−2	−1	0	0	0	7	0	0	0			
Second Derivative		−1	0	0	0	0	1	0	6	−12	6	0	0	1	1	−4	1	1	0	0	7	−7	0	0			

梯度的計算

- 假定是二維影像的灰階值函數，則灰階變化梯度是一個表示斜率變化（坡度）的向量，則影像的梯度(gradient)定義成

$$\nabla f(x,y)=\begin{bmatrix}\dfrac{\partial f(x,y)}{\partial x}\\ \dfrac{\partial f(x,y)}{\partial y}\end{bmatrix}=\begin{bmatrix}G_x\\ G_y\end{bmatrix}$$

- 其中 Gx 代表水平方向之梯度值
  Gy 代表垂直方向之梯度值

梯度的計算

- 計算梯度值的方式有下列幾種：

$$\nabla f(x,y) = \sqrt{G_x^2 + G_y^2}$$

$$\nabla f(x,y) = |G_x| + |G_y|$$

$$\nabla f(x,y) = \max\left[|G_x|, |G_y|\right]$$

Sobel (一階導函數應用)

- Sobel遮罩加重中間像素的權重，其遮罩如下所示：

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

G_X

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

G_Y

$$f'(x) = \lim_{\Delta x \to 0} \frac{f(x+\Delta x) - f(x)}{\Delta x} = \frac{f(x+1) - f(x)}{1} = f(x+1) - f(x)$$

Sobel

- 若以此公式算梯度值： $\nabla f(x,y)=\sqrt{G_x^2+G_y^2}$

0	0	0	0	0	0	0
0	6	6	6	6	6	0
0	6	6	6	6	6	0
0	6	6	6	6	6	0
0	6	6	6	6	6	0
0	6	6	6	6	6	0
0	0	0	0	0	0	0

x	x	x	x	x	x	x
x	25	24	24	24	25	x
x	24	0	0	0	24	x
x	24	0	0	0	24	x
x	24	0	0	0	24	x
x	25	24	24	24	25	x
x	x	x	x	x	x	x

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

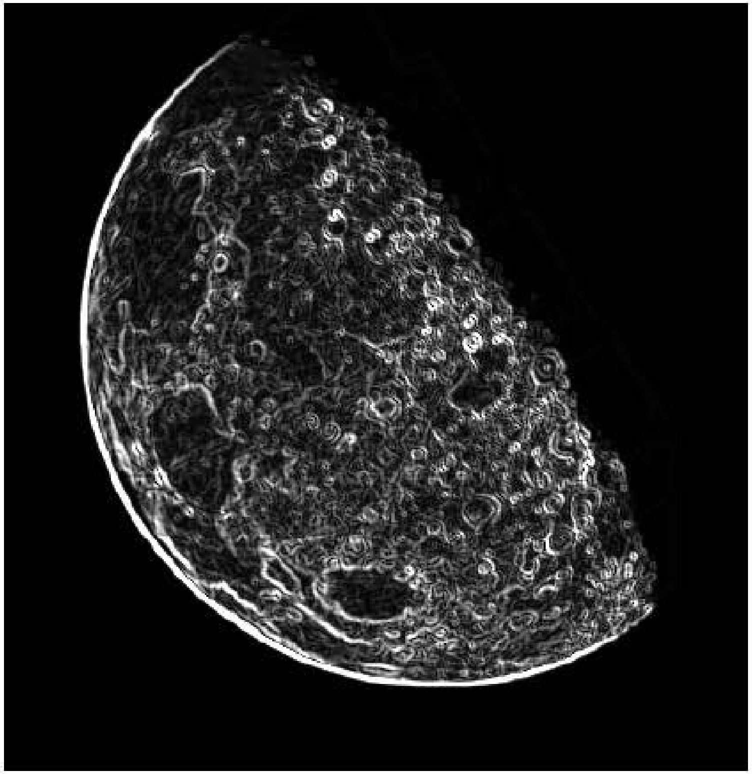
Gx

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

Gy

Sobel

Original



Sobel edge

Sobel

Original

Sobel

Laplacian (二階導函數應用)

- Laplacian filter是一種空間二階導數的運算子，它對於影像中快速變化的區域(包含edge)具有很大的強化作用
- 一維的一階導數：

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

- 一維的二階導數：

$$\frac{\partial^2 f}{\partial x^2} = f(x+1) + f(x-1) - 2f(x)$$

Laplacian

- 二維的二階導數：　$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}.$

$$\frac{\partial^2 f}{\partial x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y)$$

	1 f(x-1,y)	
	-2 f(x, y)	
	1 f(x+1,y)	

$$\frac{\partial^2 f}{\partial y^2} = f(x, y+1) + f(x, y-1) - 2f(x, y)$$

1 f(x,y-1)	-2 f(x, y)	1 f(x,y+1)

0	1	0
1	-4	1
0	1	0

Laplacian

- Before

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

30	**30**	**30**	**30**	**30**	**30**	**30**	**20**	**10**	**10**	**10**	**10**
30	30	30	30	30	30	20	20	10	10	10	10
30	30	30	30	30	20	20	20	10	10	10	10
30	30	30	30	20	20	20	20	10	10	10	10
30	30	30	20	20	20	20	20	10	10	10	10
30	30	20	20	20	20	20	20	10	10	10	10

Laplacian

- After operation of the mask $\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$

X	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
X	0	0	0	0	-20	20	-10	10	0	0	X
X	0	0	0	-20	20	0	-10	10	0	0	X
X	0	0	-20	20	0	0	-10	10	0	0	X
X	0	-20	20	0	0	0	-10	10	0	0	X
X	X	X	X	X	X	X	X	X	X	X	X

Laplacian - Practice

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

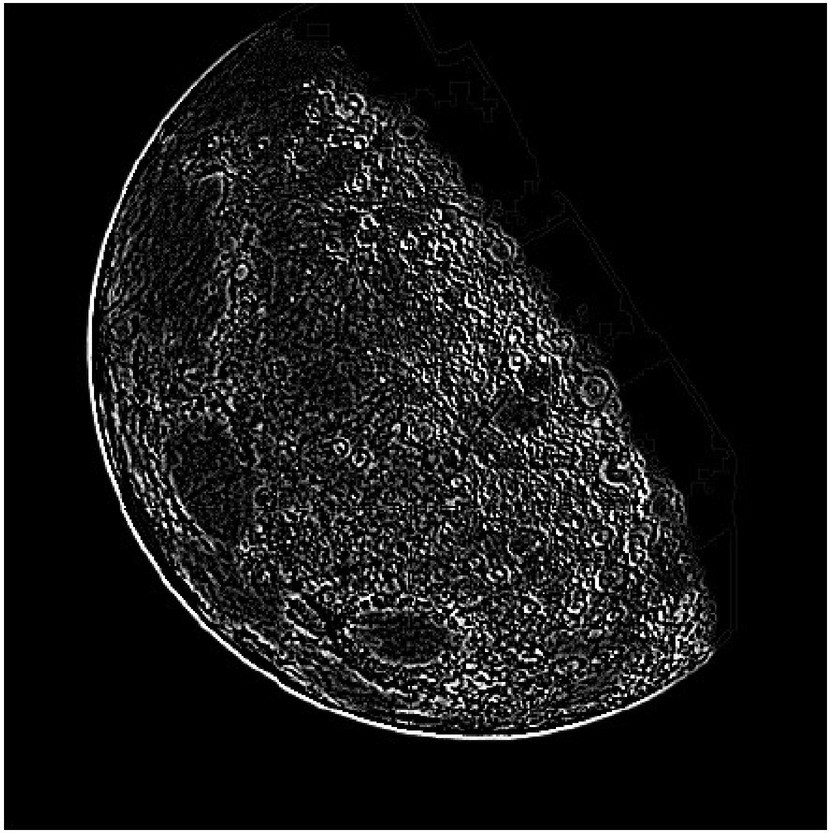
2	2	2	2	2	8	8	8	8	8
2	2	2	2	2	8	8	8	8	8
2	2	2	2	2	8	8	8	8	8
2	2	2	2	2	8	8	8	8	8
2	2	2	2	2	8	8	8	8	8
2	2	2	2	2	8	8	8	8	8

⇨

x	x	x	x	x	x	x	x	x	x
x	0	0	0	6	-6	0	0	0	x
x	0	0	0	6	-6	0	0	0	x
x	0	0	0	6	-6	0	0	0	x
x	0	0	0	6	-6	0	0	0	x
x	x	x	x	x	x	x	x	x	x

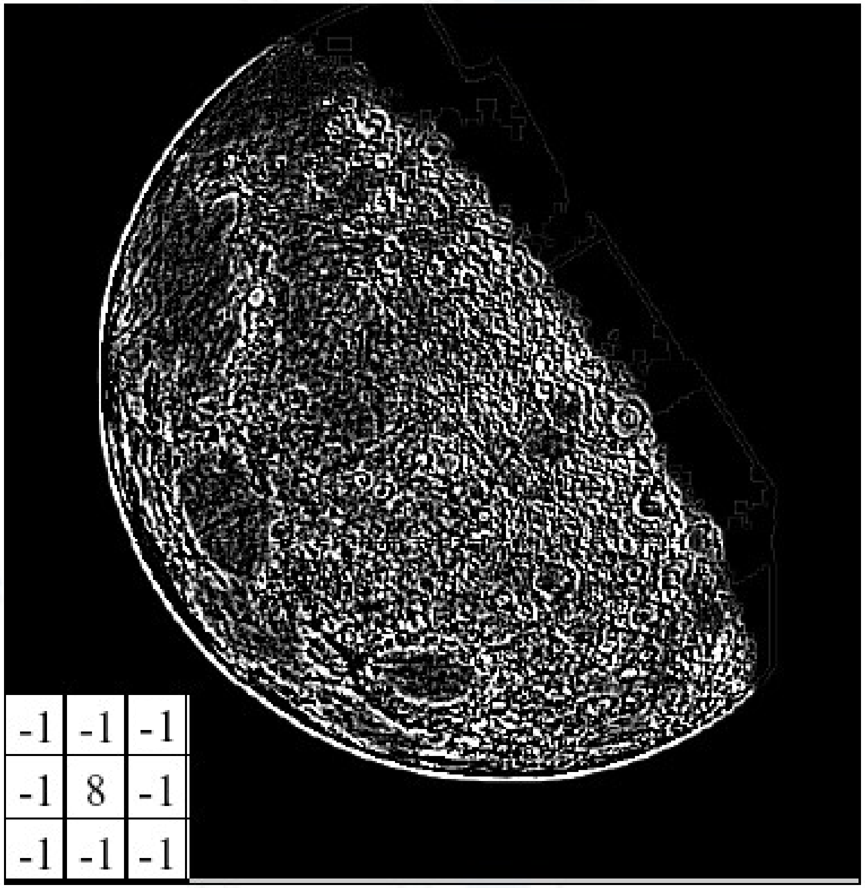
Laplacian

Original

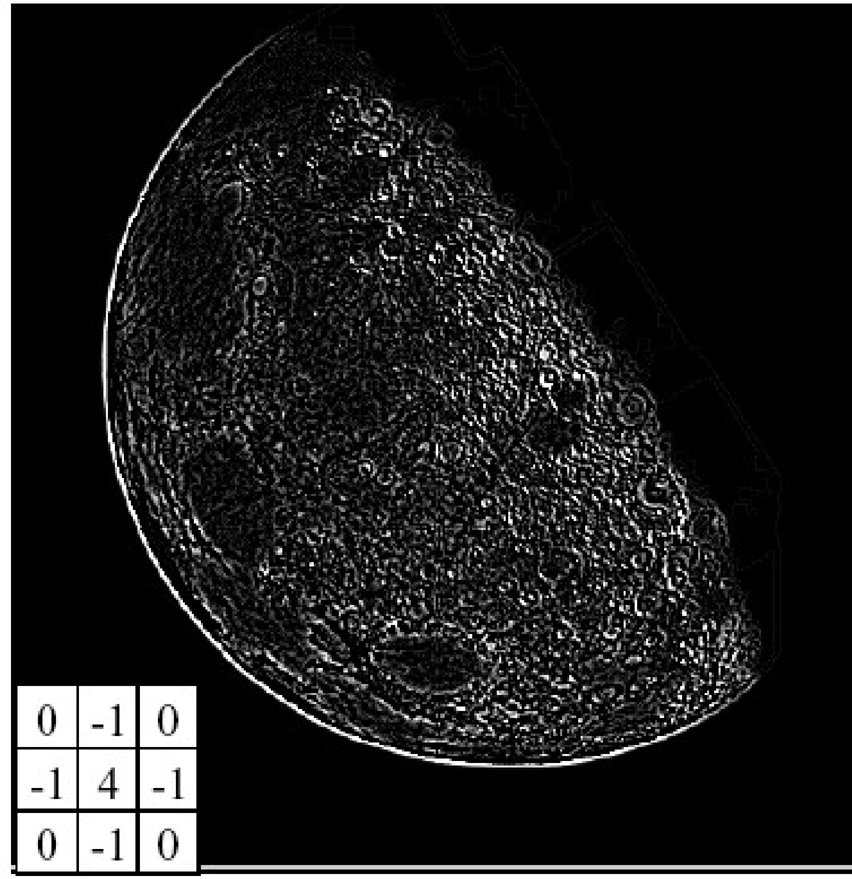


Laplacian

Laplacian



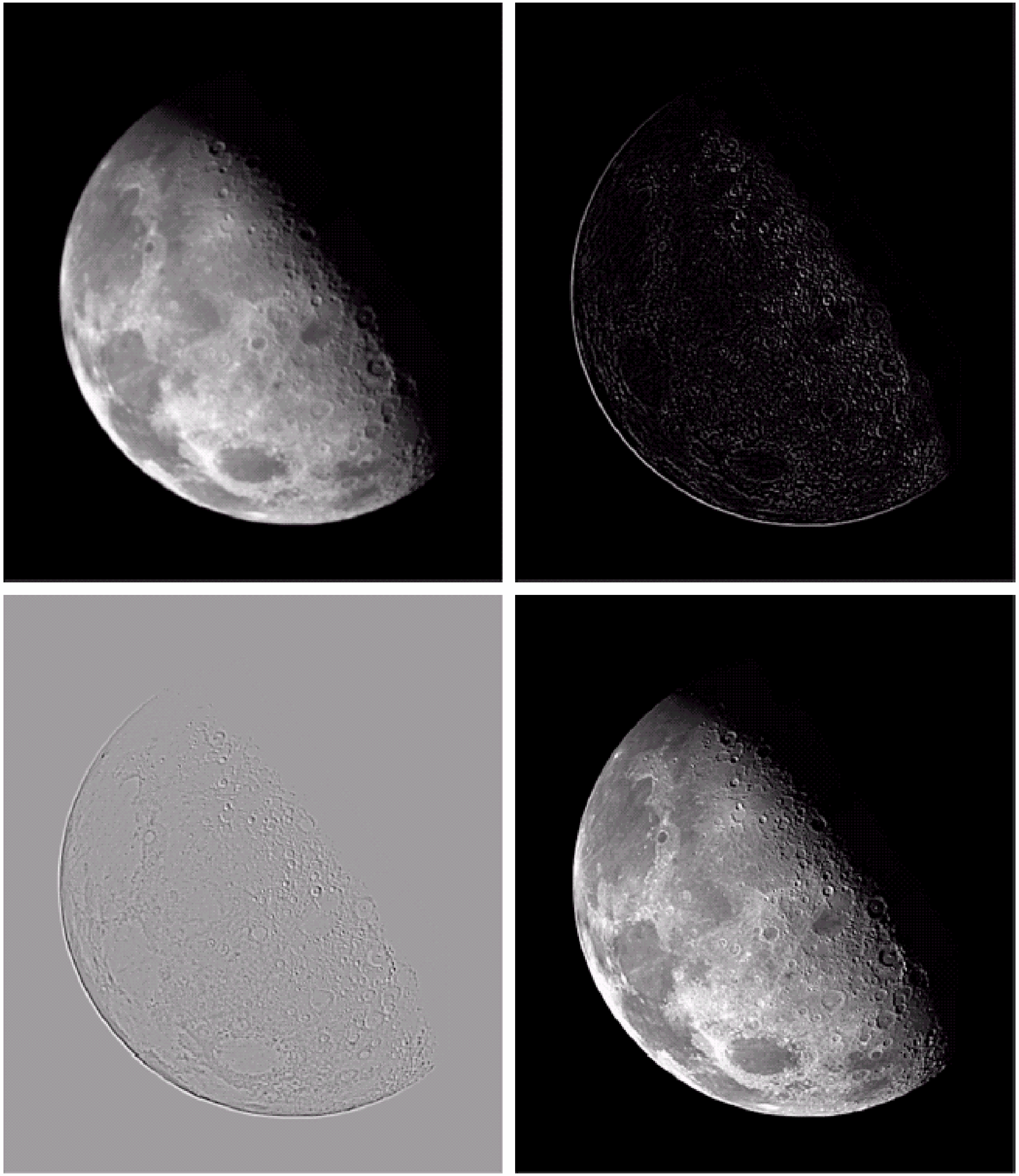
8連通 斜邊方向



4連通 垂直水平方向

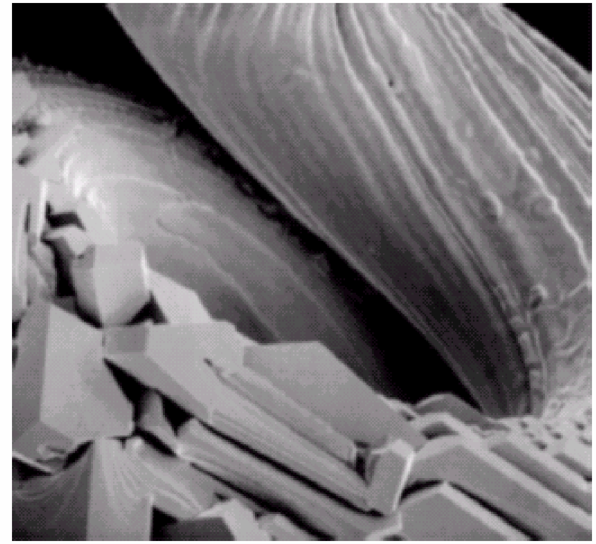
a b
c d

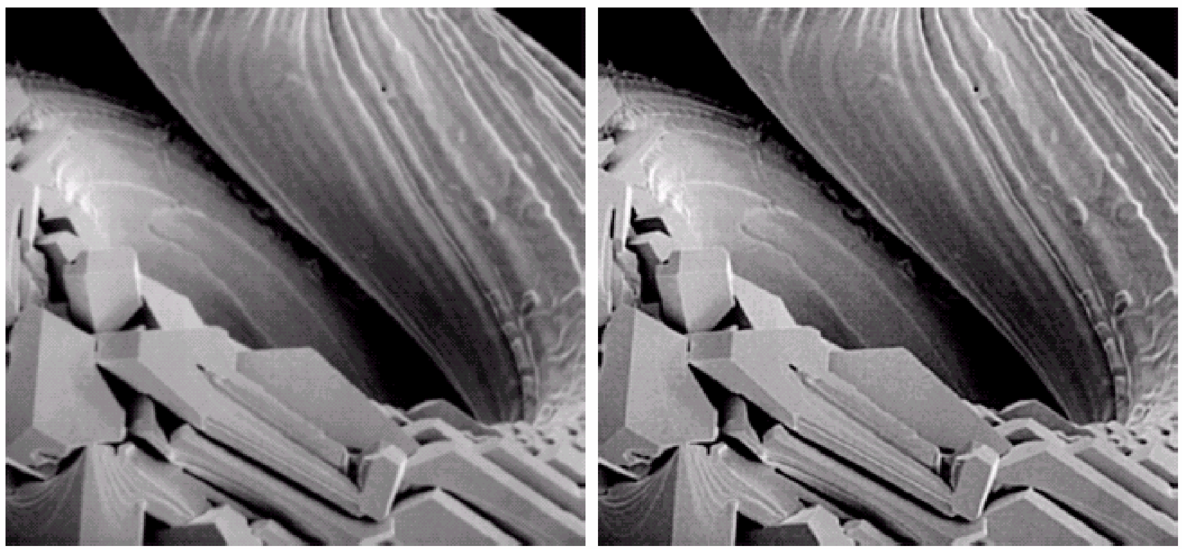
FIGURE 3.40
(a) Image of the North Pole of the moon.
(b) Laplacian-filtered image.
(c) Laplacian image scaled for display purposes.
(d) Image enhanced by using Eq. (3.7-5).
(Original image courtesy of NASA.)



0	−1	0
−1	5	−1
0	−1	0

−1	−1	−1
−1	9	−1
−1	−1	−1



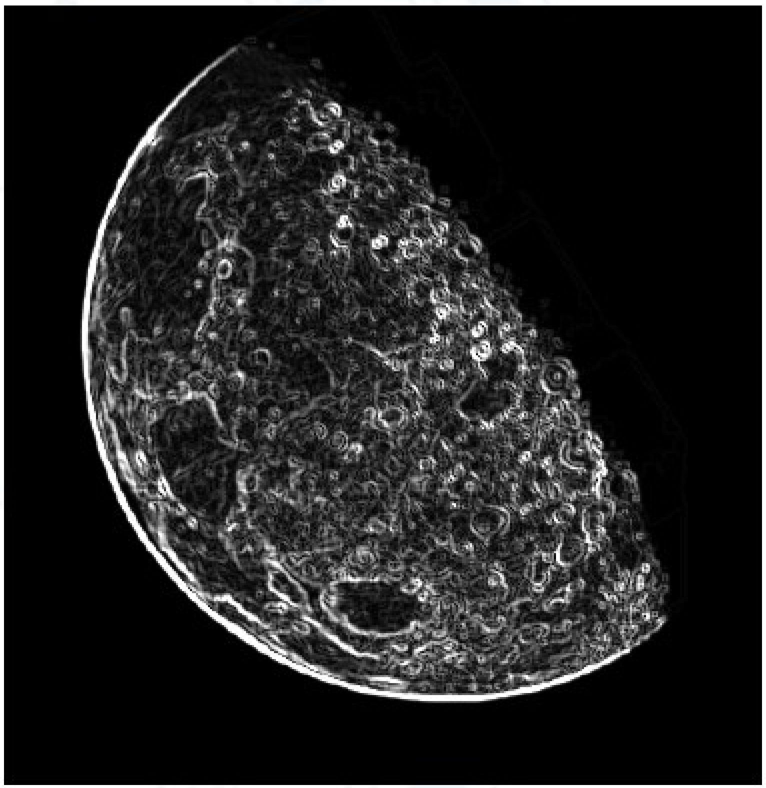


a b c
d e

FIGURE 3.41 (a) Composite Laplacian mask. (b) A second composite mask. (c) Scanning electron microscope image. (d) and (e) Results of filtering with the masks in (a) and (b), respectively. Note how much sharper (e) is than (d). (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)

Sobel 與 Laplacain 的比較

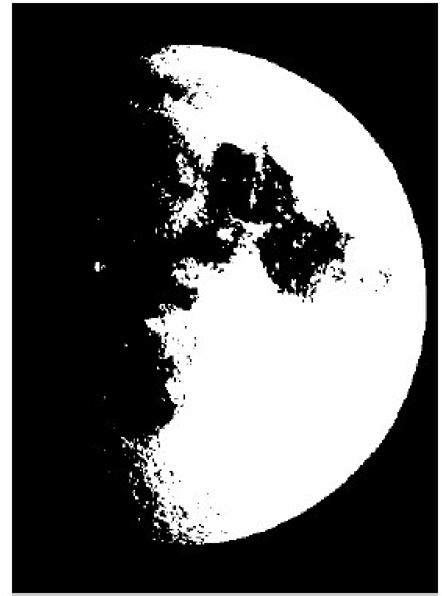
- Sobel 的邊界較寬，較模糊；但雜訊較少



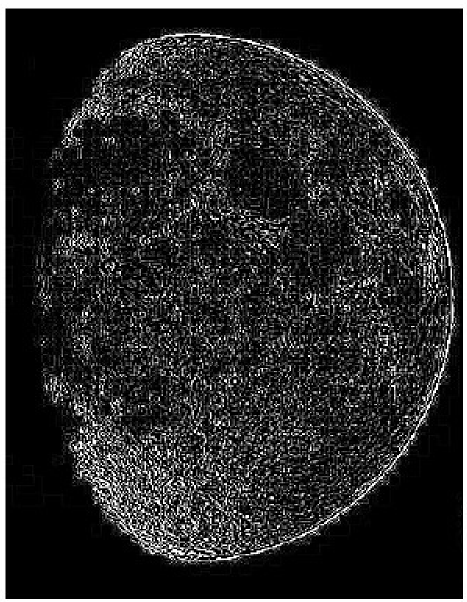
Sobel

Laplacian

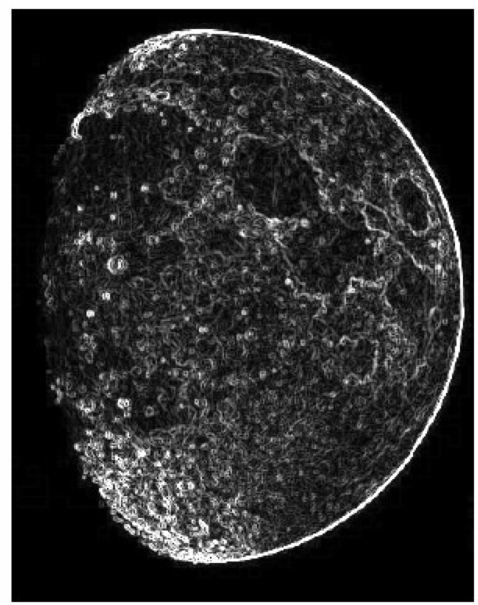
original



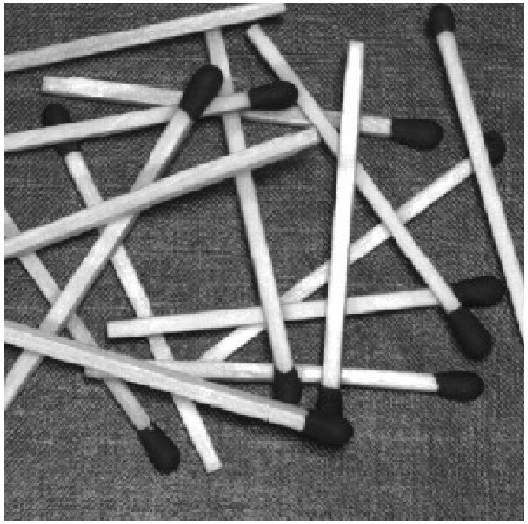
Thresholding



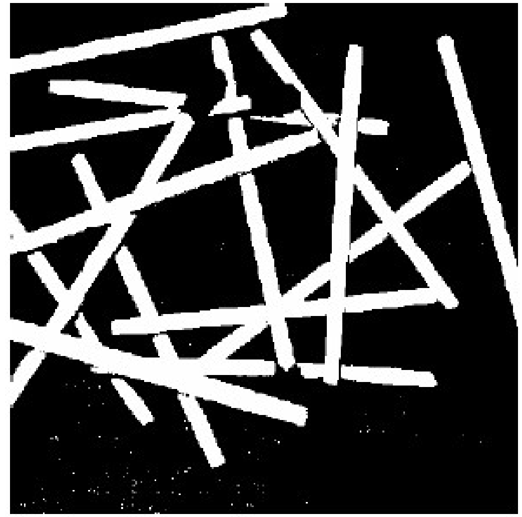
低階 Laplacian



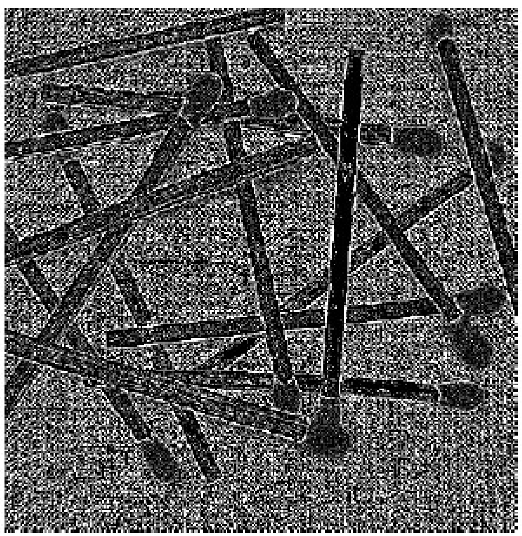
Sobel



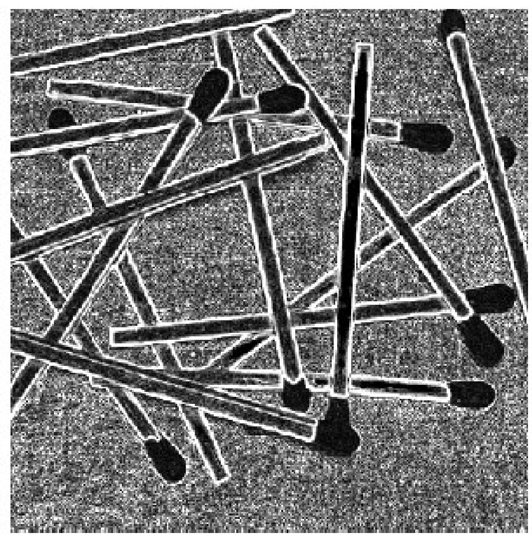
original



Thresholding



低階 Laplacian



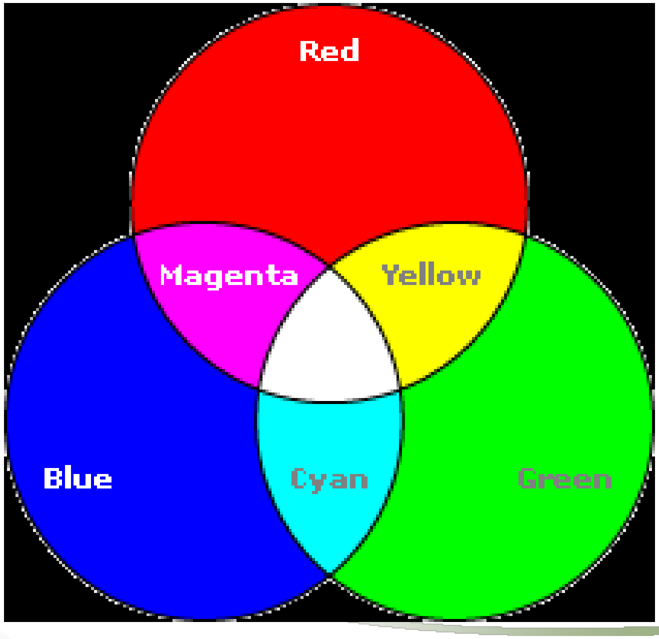
Sobel

色彩空間

- RGB
- HSV
- YCbCr
- CIE Lab

RGB

- 在RGB模型中，每種顏色是以其紅、綠、藍的主要頻譜成分來顯現。
- 每個顏色的值範圍都為0~255



HSV

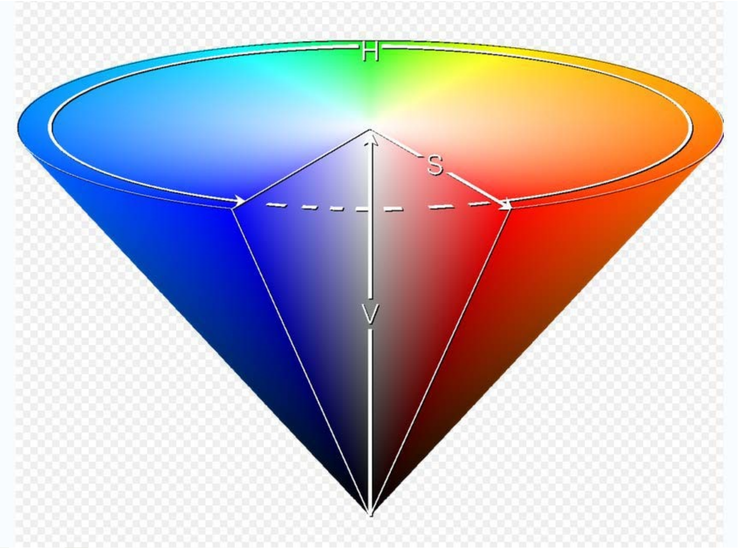
- 色調H:

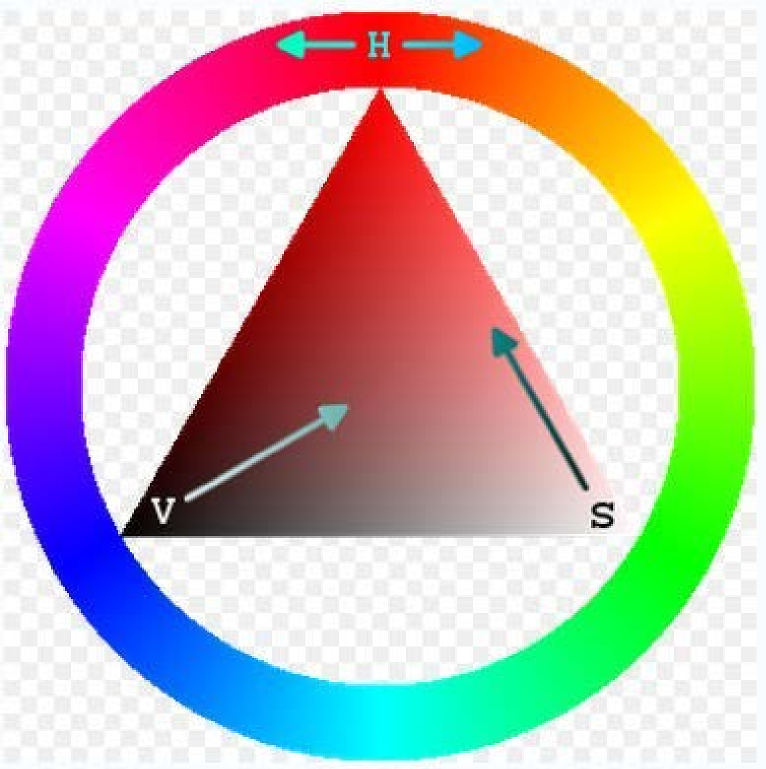
  用角度度量，取值範圍為0°～360°，從紅色開始按逆時針方向計算，紅色為0°，綠色為120°，藍色為240°。它們的補色分別是：黃色為60°，青色為180°，洋紅色300°；
- 飽和度S

  取值範圍為0.0～1.0，值越大，顏色越飽和。
- 亮度V

  取值範圍為0(黑色)～255(白色)。

HSV模型





RGB轉HSV

- max為RGB值中最大者，min為最小者。

$$h = \begin{cases} 0^\circ & \text{if } max = min \\ 60^\circ \times \frac{g-b}{max-min} + 0^\circ, & \text{if } max = r \text{ and } g \geq b \\ 60^\circ \times \frac{g-b}{max-min} + 360^\circ, & \text{if } max = r \text{ and } g < b \\ 60^\circ \times \frac{b-r}{max-min} + 120^\circ, & \text{if } max = g \\ 60^\circ \times \frac{r-g}{max-min} + 240^\circ, & \text{if } max = b \end{cases}$$

$$s = \begin{cases} 0, & \text{if } max = 0 \\ \frac{max-min}{max} = 1 - \frac{min}{max}, & \text{otherwise} \end{cases}$$

$$v = max$$

HSV到RGB

（R,G,B變化於0到1之間）：

$$h_i \equiv \left\lfloor \frac{h}{60} \right\rfloor \pmod 6$$

$$f = \frac{h}{60} - h_i$$

$$p = v \times (1 - s)$$

$$q = v \times (1 - f \times s)$$

$$t = v \times (1 - (1 - f) \times s)$$

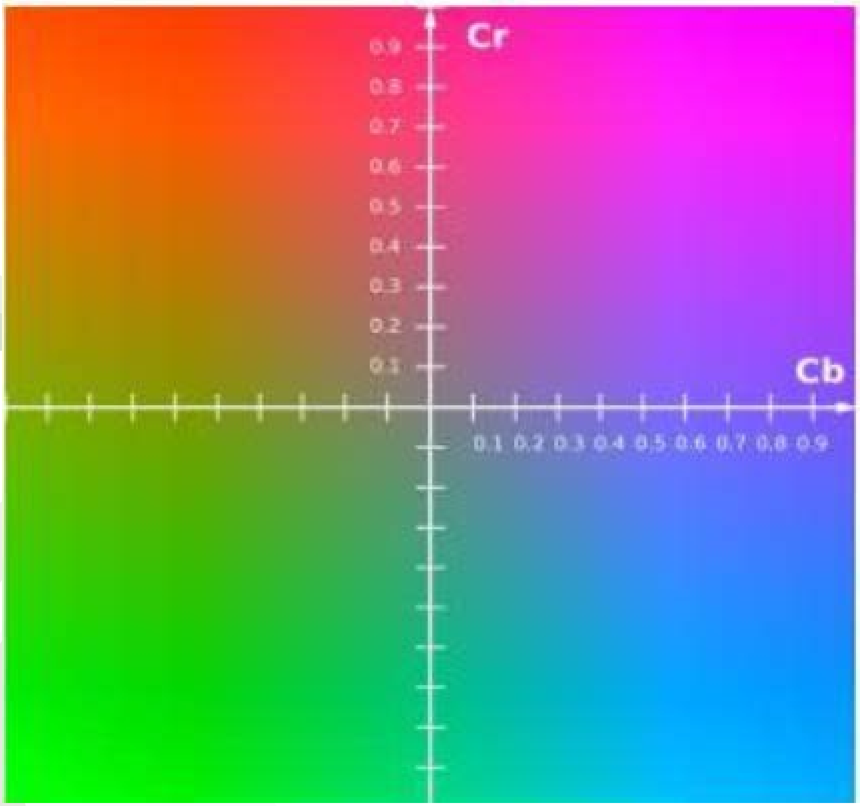
對於每個顏色向量 (r, g, b),

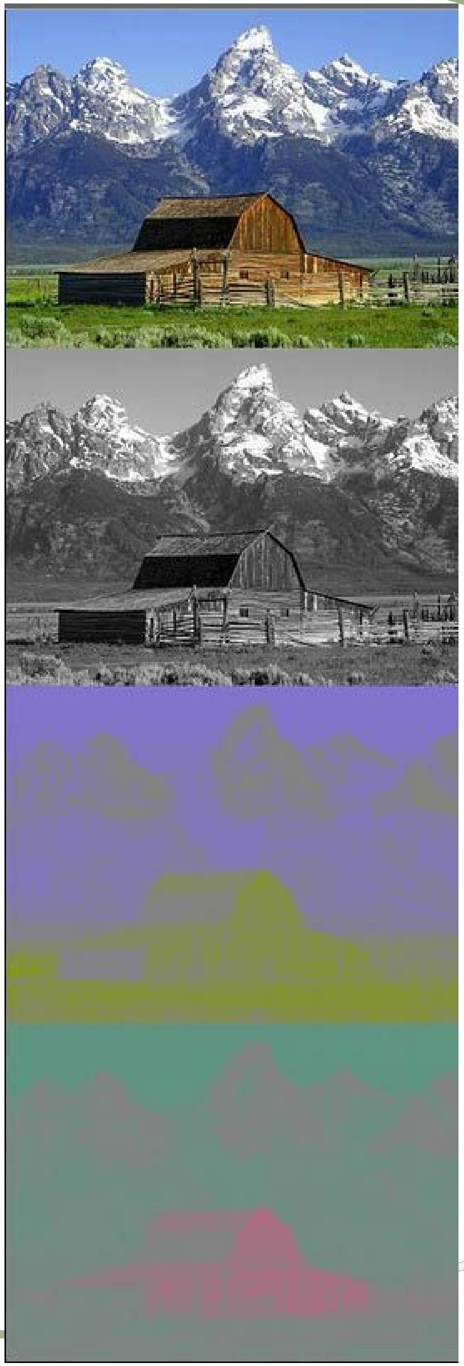
$$(r, g, b) = \begin{cases} (v, t, p), & \text{if } h_i = 0 \\ (q, v, p), & \text{if } h_i = 1 \\ (p, v, t), & \text{if } h_i = 2 \\ (p, q, v), & \text{if } h_i = 3 \\ (t, p, v), & \text{if } h_i = 4 \\ (v, p, q), & \text{if } h_i = 5 \end{cases}$$

YCbCr

- Y : 明度
- Cb : 藍色色差
- Cr : 紅色色差
- 是YUV壓縮和偏移的版本
- 影像連續處理，或是數位攝影系統中

YCbCr separation





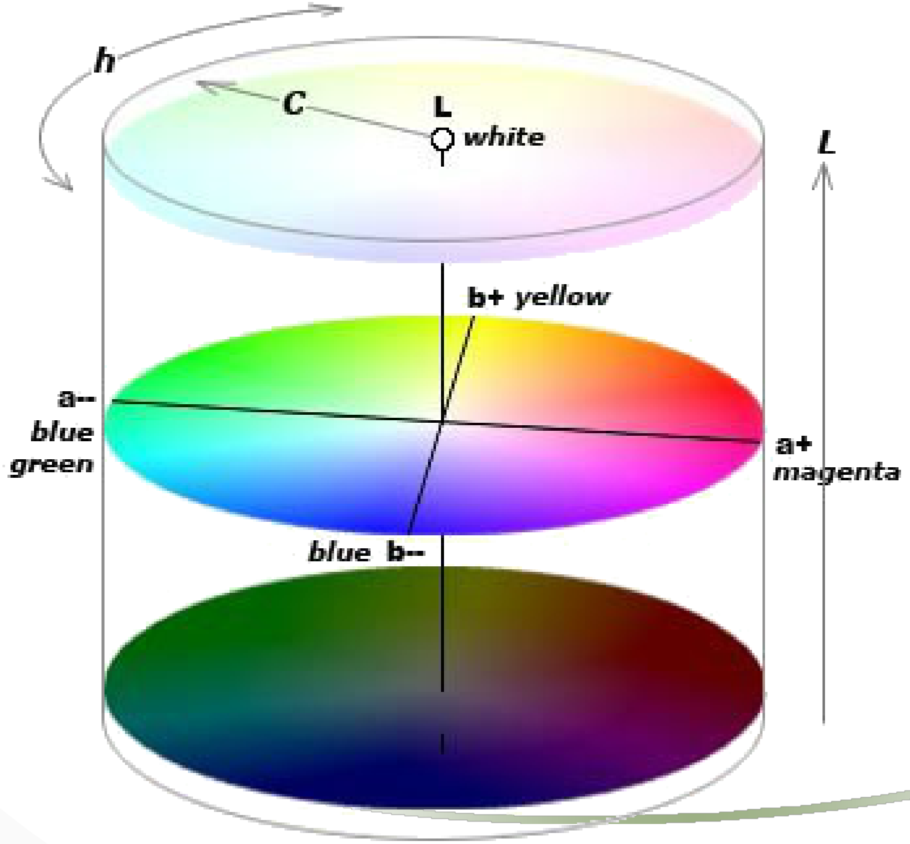
YCbCr轉換

- RGB -> YCbCr
  - Y = 0.299 R + 0.578 G + 0.114 B
  - Cb = 0.564 (B - Y)
  - Cr = 0.713 (R - Y)
- YCbCr -> RGB
  - R = Y + 1.402 Cr
  - G = Y – 0.344 Cb – 0.714 Cr
  - B = Y + 1.772 Cb

CIE Lab色彩空間

- CIE L*a*b*（CIELAB）是慣常用來描述人眼可見的所有顏色的最完備的色彩模型，具有視覺上的均勻性。

- CIE Lab顏色空間分為L、a、b三個通道，此顏色空間較RGB顏色空間更接近人類眼睛對色彩的描述。
  - L描述亮度值，範圍值介於0~100
  - a描述綠色至紫紅色，範圍介於-500~500
  - b描述藍色至黃色，範圍介於-200~200



RGB轉成CIE LAB：

- 先將RGB轉成CIE XYZ

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- 再由CIE XYZ色彩空間轉換至CIELAB色彩空間

$$L^* = \begin{cases} 116 \times \left(\frac{Y}{Yn}\right)^{\frac{1}{3}} - 16, & \frac{Y}{Yn} > 0.008856 \\ 903.3 \times \frac{Y}{Yn}, & \text{otherwise} \end{cases}$$

$$a^* = 500 \times \left(f\left(\frac{X}{Xn}\right) - f\left(\frac{Y}{Yn}\right) \right)$$

$$b^* = 200 \times \left(f\left(\frac{Y}{Yn}\right) - f\left(\frac{Z}{Zn}\right) \right)$$

where

$$Xn = 0.9515$$
$$Yn = 1.0000$$
$$Zn = 1.0886$$

$$f(t) = \begin{cases} t^{\frac{1}{3}}, & t > 0.008856 \\ 7.787 \times t + \frac{16}{116}, & \text{otherwise} \end{cases}$$

CIELAB轉RGB

先將CIELAB色彩空間轉換至CIE XYZ色彩空間，方法如下：

$$f_y = \frac{L^* + 16}{116}$$

$$f_x = f_y + \frac{a^*}{500}$$

$$f_z = f_y - \frac{b^*}{200}$$

$$\text{if} \quad f_y > 0.008856 \quad \text{then} \quad Y = Yn \times f_y^{\,3}$$

$$\text{else} \quad Y = \left(\frac{f_y - 16}{116}\right) \times 3 \times 0.008865^2 \times Yn$$

$$\text{if} \quad f_x > 0.008856 \quad \text{then} \quad X = Xn \times f_x^{\,3}$$

$$\text{else} \quad X = \left(\frac{f_x - 16}{116}\right) \times 3 \times 0.008865^2 \times Xn$$

$$\text{if} \quad f_z > 0.008856 \quad \text{then} \quad Z = Zn \times f_z^{\,3}$$

$$\text{else} \quad Z = \left(\frac{f_z - 16}{116}\right) \times 3 \times 0.008865^2 \times Zn$$

再由CIE XYZ色彩空間轉換回RGB色彩空間，轉換矩陣如下：

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3.240479 & -1.537150 & -0.498535 \\ -0.969256 & 1.875992 & 0.041556 \\ 0.055648 & -0.204043 & 1.057311 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

最後，將RGB的範圍由0~1調整為0~255。

Homework 4-1

- 利用Sobel 的兩個mask

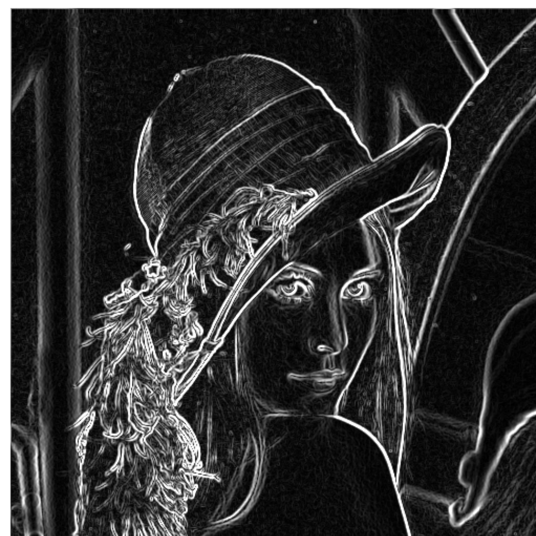
-1	0	1
-2	0	2
-1	0	1

G_X

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

G_Y

- 以及公式 $\nabla f(x,y)=\sqrt{G_x^2+G_y^2}$ 來求得梯度值



Homework 4-2

- **RGB to HSV (公式轉換)**

$$h = \begin{cases} 0^\circ & \text{if } max = min \\ 60^\circ \times \frac{g-b}{max-min} + 0^\circ, & \text{if } max = r \text{ and } g \geq b \\ 60^\circ \times \frac{g-b}{max-min} + 360^\circ, & \text{if } max = r \text{ and } g < b \\ 60^\circ \times \frac{b-r}{max-min} + 120^\circ, & \text{if } max = g \\ 60^\circ \times \frac{r-g}{max-min} + 240^\circ, & \text{if } max = b \end{cases}$$

$$s = \begin{cases} 0, & \text{if } max = 0 \\ \frac{max-min}{max} = 1 - \frac{min}{max}, & \text{otherwise} \end{cases}$$

$$v = max$$