Image Processing / NCTU Fall 2021 Exam #1 (11/12/2021) Name: 趙秉濂 ID: 310552011

This is a closed-book exam. You can answer with either English or Chinese.

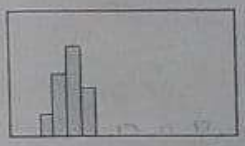
Prob#	1	2	3	4	5	6	7	8	9	Total
Score	4	15	9	10	8	10	15	5	16	92

1. [4%] Consider the region of white pixels in the image here. How many connected components are there according to 4-connectivity and 8-connectivity, respectively?

+4

6 components 2 components

2. [15%] For one 16-gray-level image, its intensity histogram is shown to the right:



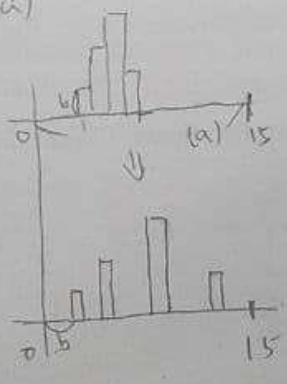
(a) Sketch the likely resulting histogram after histogram equalization. Explain the reasoning behind your sketch.

(b) If you want to enhance this image with power-law intensity transform, what kind of gamma value (>1, =1, or <1) should you use? Explain briefly.

(c) Noise, if present in this image, will be enhanced after histogram equalization. Explain briefly.

+15

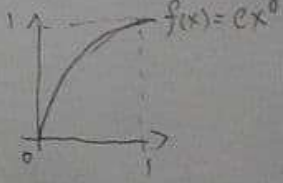
(a)



假設 x 軸長 (a) 與柱高和相同
新的 pixel 值會是柱高 (如 b 所示)
(HE轉換後)

#

(b) 數值偏低，增強低數值的對比，取 gamma <1



(c) 會被增強，因為 HE 後值之間的空間 (Gap) 變大
因此 noise 會更明顯

3. [10%] Use Sobel filters to compute the gradient direction of the center pixel of the 3x3 region shown to the right.

0	0	1
0	1	2
0	2	2

+9 Sobel filters

$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$ 垂直 ⇓ 5

$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$ 水平 ⇓ 7

$\begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$ 左 45° ⇓ 8

$\begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$ 右 45° ⇓ -2

4. [10%] Answer the following questions regarding CMY and CMYK color models:
(a) What colors do the letters in CMY and CMYK stand for? Magenta.
(b) How are the CMY colors related to RGB?
(c) CMY is the standard color space used in color printing. Why using CMY instead of RGB?
(d) Explain the reason why CMYK, instead of CMY, is used in modern color printers?

(a) C: cyan ; M: magenta ; Y: yellow ; K: black

(b) 這裡的CMY，RGB數值為0與1之間 $\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1-R \\ 1-G \\ 1-B \end{bmatrix}$

ex: cyan 是減少紅光，在RGB表示為 $\begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$ ($\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$)

(c) 印刷時，塗上顏料是減少反射光，故用減少光的 CMY表示容易印刷

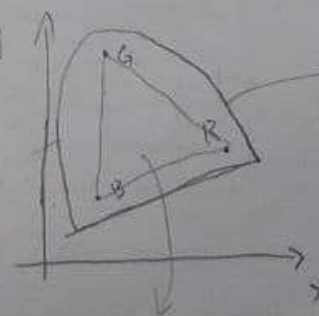
(d) K是CMY混合而成，列印時常有顏不純或不易乾的問題，又黑色是常用色，故增加黑色的向度。

5. [10%] Regarding color gamuts:
(a) A color gamut is displayed in a 2-D space with x and y ordinates. What do the two axes stand for, and how are they related to the light sensing cells in the retina? 視網膜
(b) Approximately sketch the "region of all visible colors" in this x-y space.
(c) What is the reason that the color gamuts of typical color displays are triangles in this space? What do the three corners of the triangle stand for?

−1

(a) x代表紅視錐細胞受刺激的比例
y代表綠視錐細胞受刺激的比例

(b)



三角形是人類可辨視的顏色範圍 *

−1

(c) 顯示器的顏色為 R, G, B 三種光的線性組合
故可能性限制在三角形內
三個角代表 Red, Green, Blue.

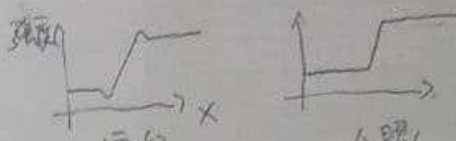
6. [10%] Regarding image sharpening:
(a) Give a typical 3x3 Laplacian filter.
(b) Explain how the filter can be used for image sharpening.
(c) Explain what the visual effect of "Mach band" is, and how it is related to image sharpening.

(a)
$$\begin{matrix}0&1&0\\1&-4&1\\0&1&0\end{matrix}$$
✓ +3 ※

(b) 原圖 − Laplacian = sharp

$$\begin{matrix}0&0&0\\0&1&0\\0&0&0\end{matrix} - \begin{matrix}0&1&0\\1&-4&1\\0&1&0\end{matrix} = \begin{matrix}0&-1&0\\-1&5&-1\\0&-1&0\end{matrix}$$
✓ +3 ※

(c) Mach band
人眼會對邊界顏色減弱



✓ +4

sharpen 可以增強邊界來補足 Mach band 的視差 ※

7. [15%] Consider the methods for automatic threshold selection.
(a) List the steps of the Basic Global Method as described in the textbook/lecture.
(b) Explain how you can extend the procedure in (a) to cases with multiple thresholds.
(c) Uneven illumination often causes problem in threshold selection. An example is shown to the right. Describe a method to improve the thresholding of this image so that the text in the image can be extracted.

(a) ① 選定一個 treshold = T (可以取全體平均)

② 計算小於 T 的 pixel 的平均 a_1
計算大於等於 T 的 pixel 的平均 a_2

③ $T_{new} = (a_1 + a_2)/2$, 回到①重覆做, 直到 $(T - T_{new}) < \varepsilon$ converge.
以 T_{new} 做為新的 T
✓ +5

(b) 分 n 塊 (n-1 個 T)

① 取 $T_1, T_2 \cdots T_{n-1}$, 令 $T_0 = 0$, T_n = max level of pixel

② a_i = avg(p), $p \in [T_{i-1}, T_i]$

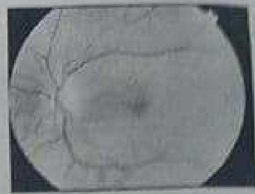
③ $T_{i\_new} = (a_i + a_{i+1})/2$, 更新 T_i 回到②重覆做到 converge
✓ +5

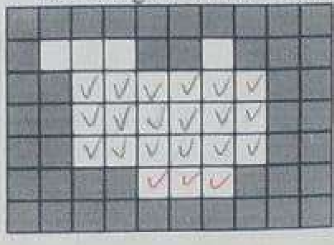
(c) 使用 adaptive automatic threshold
將圖片分成 6 塊, 分別做 automatic threshold
這樣可以對應區域的光線來調整 threshold 大小
✓ +5

8. [10%] A little about mathematical morphology:

(a) For the binary image below (white pixels as "1" and gray pixels as "0"), indicate the "1" pixels after morphology opening with a 3x3 structuring element (all 9 pixels in the 3x3 included). You can directly mark those pixels in the "image".

(b) Top-hat and bottom-hat transforms are typical used to extract thin structures in images; an example is shown to the right. Describe the steps involved in this case, including the individual morphological operators used.





(a) ✓ 代表 open 後 pixel "1" 的位置
其它是 "0"

-(b)

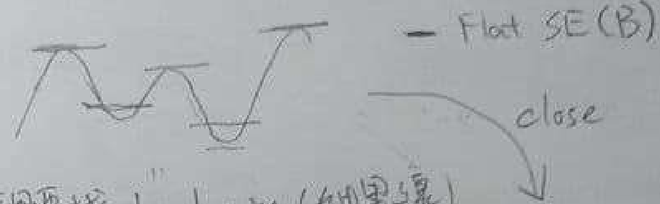


Image → A
- Flat SE → B

這裡要找 local min (細黑線)
用 bottom-hat $(A \cdot B) - A$ #

+5

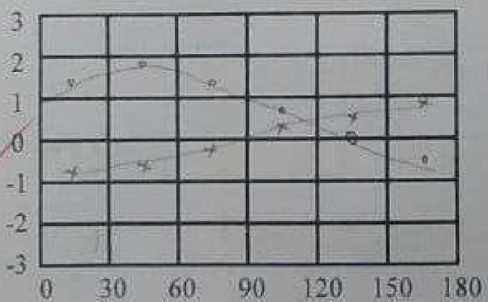
9. [16%] An image contains only two foreground pixels at (-1,0) and (1,1). Use Hough transform to find the equation of the most significant line. The line equation in polar coordinates is $x\cos\theta + y\sin\theta = \rho$.

(a) Why do we use the polar-coordinate representation of lines, not the simpler $y=ax+b$?

(b) Fill the given accumulation bins below. The resolutions of the accumulation bins are 30° for θ and one pixel for ρ. Use cos(45°)=sin(45°)=0.7, cos(75°)=sin(15°)=0.25, and cos(15°)=sin(75°)=0.95.

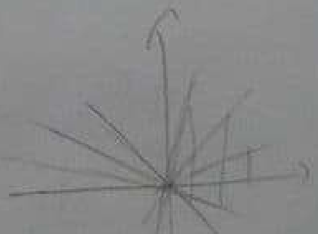
(c) Determine the equation of the most significant line.

+6



+5

(a) 因為 a (斜率) 的範圍沒有界限，無法用有限的可能性來找共線 (若用 $y=ax+b$，左圖的軸要到 [-∞, ∞])



(b)

θ	(-1,0)	(1,1)	f(x,y)=ρ
15°	-0.95	1.2	0.95x + 0.25y
45°	-0.7	1.4	0.7x + 0.7y
75°	-0.25	1.2	0.25x + 0.95y
✓ 105°	0.25	0.7	-0.25x + 0.95y
135°	0.7	0	-0.7x + 0.7y
165°	0.95	-0.7	-0.95x + 0.25y
mark	x	o	

(c) +5

$-0.25x + 0.95y = 0.5$ #