EE 569 Discussion

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Midterm1 logistics

- Mar. 2 (next Wednesday) 8:00 am – 10:00 am
- Open book (paper-based resources only, such as textbook, lecture notes written on a notebook, or cheatsheet)
- Usages of computer, mobile phone, Internet, calculator are NOT allowed

- Online exam using D2L – quiz tool
- No Q&A for exam content during the test
  - We have made question descriptions as clear as possible and there is no typo.
  - If you need some assumptions which are not stated in the problem description, write them down in your answer and continue on the problem.
  - If you still need to ask questions, post private question on Piazza.
- Make sure your have a stable Internet connection!

Midterm1 logistics

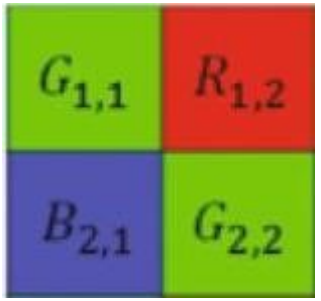
- Exam range
  - Topic #1 ~ Topic#4
  - What you need to review
    - Algorithms you implemented (understand how they work)
    - Lecture notes
- Question types
  - Matching problem (or multi-choice)
  - Written response question (no extensive calculation)
- Make sure you have finished all problems before submission
  - There are multiple pages
  - Check the question answering state listed
  - You can only submit once

Demosaicing

A CFA image of size 5x5 is shown in Fig. 1.1 (b) and its corresponding Bayer pattern is shown in Fig. 1.1(a).

(a) Estimate the missing red and green values at pixel at the image center location with (x,y)= (2, 2) using bilinear interpolation. Show the formula in obtaining your solution. (4 pts.)

(b) Estimate the missing blue and red values at pixel at the image center location with (x,y)= (3, 2) using bilinear interpolation. Show the formula in obtaining your solution. (4 pts.)



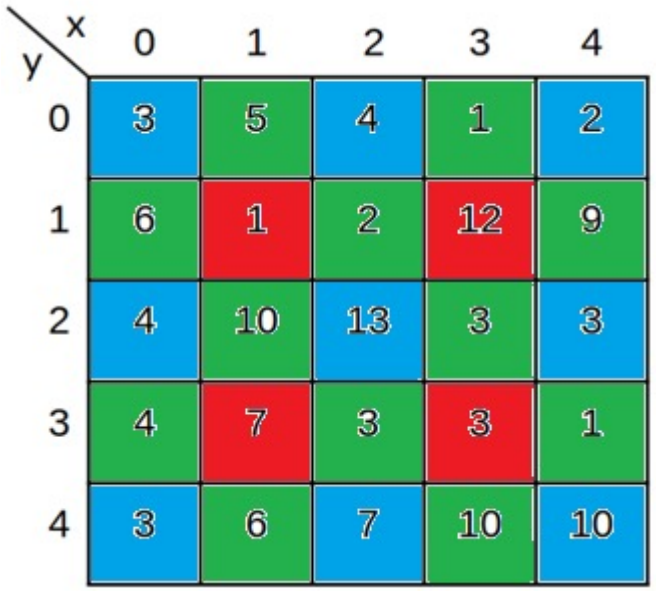
Different from the pattern in homework!

(a) Bayer pattern

y \ x	0	1	2	3	4
0	3	5	4	1	2
1	6	1	2	12	9
2	4	10	13	3	3
3	4	7	3	3	1
4	3	6	7	10	10

(b) A CFA image

Figure 1.1



y \ x	0	1	2	3	4
0	3	5	4	1	2
1	6	1	2	12	9
2	4	10	13	3	3
3	4	7	3	3	1
4	3	6	7	10	10

(a)

$$R_{2,2} = \frac{1}{4}\left(R_{1,1} + R_{1,3} + R_{3,1} + R_{3,3}\right)$$

$$= \frac{1}{4}(1 + 12 + 7 + 3) = \frac{23}{4} = 5.75\ (5\ or\ 6)$$

$$G_{2,2} = \frac{1}{4}\left(G_{2,1} + G_{2,3} + G_{1,2} + G_{3,2}\right)$$

$$= \frac{1}{4}(10 + 3 + 2 + 3) = 4.5\ (4\ or\ 5)$$

(b)

$$R_{3,2} = \frac{1}{2}\left(R_{3,1} + R_{3,3}\right) = \frac{1}{2}(7 + 3) = 5$$

$$B_{3,2} = \frac{1}{2}\left(B_{2,2} + B_{4,2}\right) = \frac{1}{2}(13 + 7) = 10$$

Histogram Manipulation

Tommy Trojan applied various transfer functions to the *cameraman* image and produced different results. Please match each specific transfer function labeled by (1)-(5) to five possible output images labeled by (A)-(E). Justify your answer.

Original image

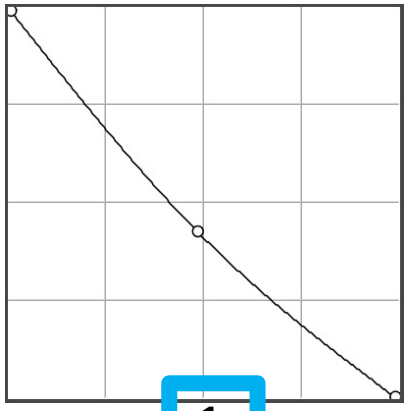
A

B

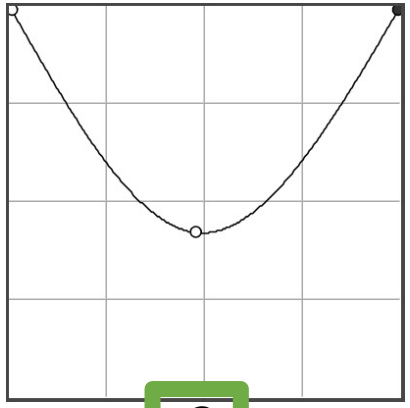
C

D

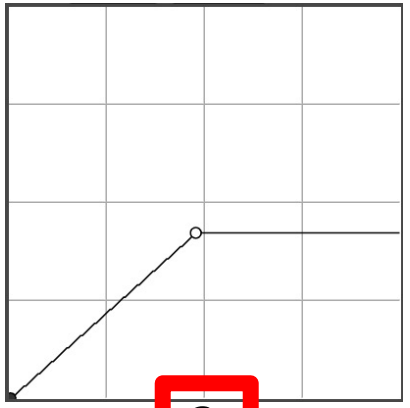
E



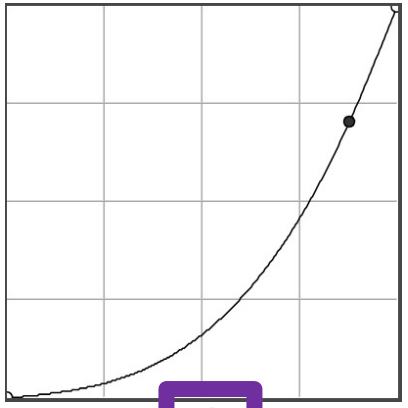
1



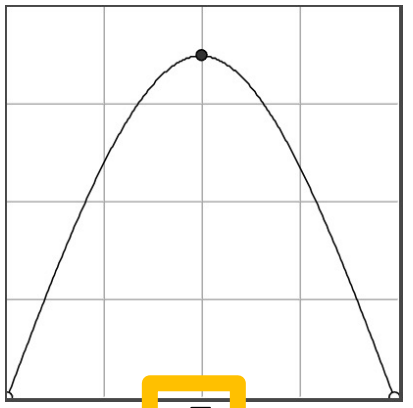
2



3



4



5

Solution

- A-2: Those very dark parts (coat) become very bright, and the original bright parts (base of the camera) are still bright.
- B-3: Lower overall intensity compared to the original image, and no very bright pixels (easy to observe on the bars supporting the camera).
- C-4: Lower overall intensity, and gray parts (sky and river) are darker now, but there are still very bright pixels (camera base).
- D-1: Totally reversed color, like the coat and the bars supporting the camera.
- E-5: Pixels that are originally of low intensity now become brighter, and the original super white part on the camera (camera base) now is nearly total black.

Poor answers – example 1

- A-2
- B-3
- C-4
- D-1
- E-5

✖ No justifications!

Poor answers – example 2

- A-2: Those very dark parts (coat) become very bright, and the original bright parts (base of the camera) are still bright.
- B-3: Lower overall intensity compared to the original image, and no very bright pixels (easy to observe on the bars supporting the camera).
- C-4: That's the only one left :P 
- D-1: Totally reversed color, like the coat and the bars supporting the camera.
- E-5: Pixels that are originally of low intensity now become brighter, and the original super white part on the camera (camera base) now is nearly total black.

True or False

- “A low-pass filter can sharpen the image while reducing noises.”

  False.

  Weighted average can only blur the edges. Different denoising methods have different extent of blur.

- “Bilateral filter can help keep the edges while denoising.”

  True.

  Bilateral filter applied Gaussian filter not only according to the pixel’s geometric closeness, but it also considers the closeness between the pixel values. Thus, it is good at preserving edges.

Edge detection

- Sobel: 1st order derivative edge detection method
  1) How to do Sobel?
     a. Gx: horizontal gradient, capture vertical edges
     b. Gy: vertical gradient, capture horizontal edges

  2) What are gradient maps and magnitude maps look like? Why?

  3) What's disadvantage of Sobel?
     a. Sensitive to noise
     b. Not thin edge

  4) 2nd order derivative edge detection method:
     a. ex. LoG
     b. Why use 2nd order?

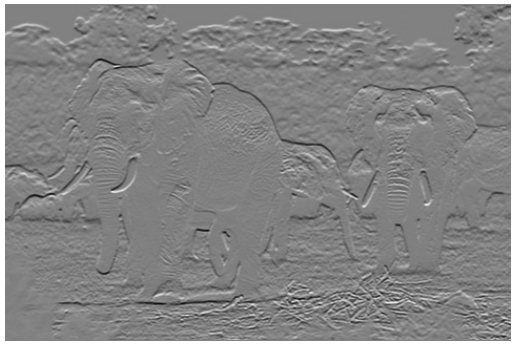
-1	0	+1
-2	0	+2
-1	0	+1

Gx

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

Gy

Gx map



Gy map

Sample exam problems

d. What are the major steps of Sobel edge detector? (3 pts.)

i. Compute Horizontal gradient, compute vertical gradient
ii. Compute magnitude of gradient
iii. Thresholding

e. Suggest one way to improve one of the drawbacks of Sobel edge detector? Include the drawback that you are dealing with in your answer. (3 pts.)

i. Sensitive to noise: apply gaussian filter before Sobel
ii. Not thin edge: apply NMS

Edge detection

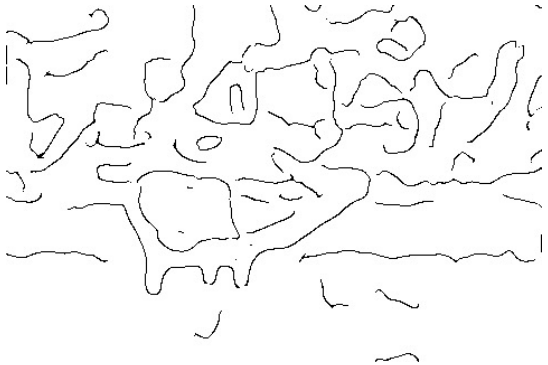
- Canny
  1) Steps:
     a. gaussian filtering (different sigma influences)
     b. calculate gradient maps, magnitude maps
     c. NMS
     d. Double hysteresis thresholding (different pair of threshold result)
  2) Each step's purpose
  3) Why better than Sobel?
     a. Canny has Gaussian filtering step → effect
     b. NMS step → effect
     c. Double thresholding → effect

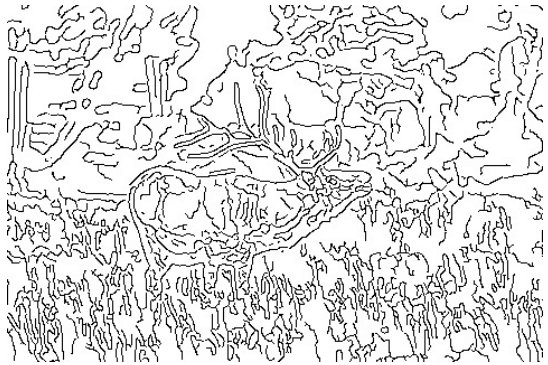
Sample exam problems

a. What is the purpose of hysteresis thresholding in Canny edge detector? What are the two major (user-defined) parameters for hysteresis thresholding? Briefly explain the process. (5 pts.)

Purpose: use neighborhood information to determine which edges are really edges and what are not. So that to increase the connectivity of edges

b. The following three edge maps are generated using the Canny edge detector. They differ in the value of σ (standard deviation) used. Rank the three output images based on σ from high to low.





Edge detection

- Structured edge
  - Data-driven edge detector, involve training, validation and testing splitting
  - Use machine learning algorithm, random forest

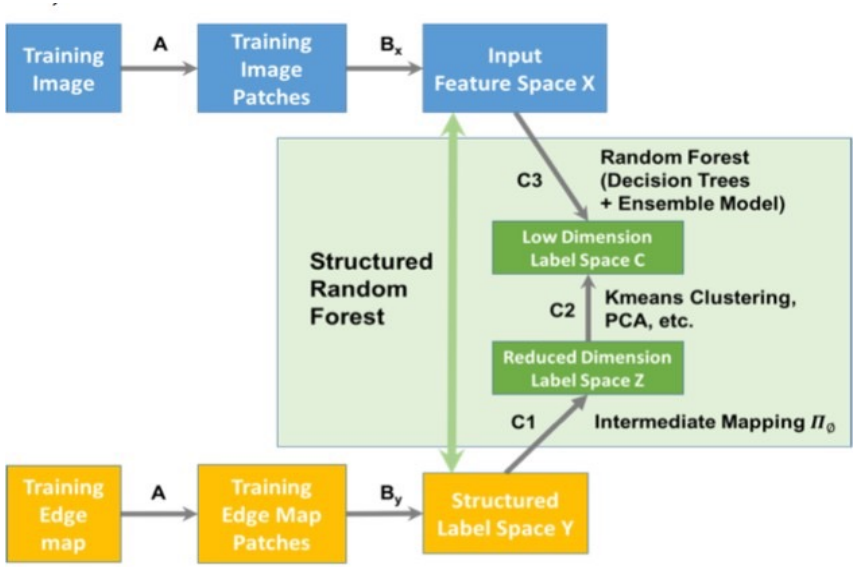


Figure 2-8 Structured Edge Detector flow chart (Training)

  - Difference with Sobel, Canny?

Sample exam problem

c. How is Structured Edge different from traditional edge detectors like Sobel, LOG and Canny? (3 pts.)

i. Data-driven edge detector, involve training, validation and testing splitting
ii. Use machine learning algorithm, random forest
iii. Use larger patch information to do decision instead of single pixel

Digital halftoning

- Dithering: How to choose threshold? Difference in result image
  - Fixed threshold: 127 or 128
  - Random threshold
  - Dithering matrix (ordered dithering)
- Dithering matrix:
  - Different effect of I2, I4, I8
  - All have block pattern, difference in pattern detail

$$I_2 = \frac{1}{4} \times \begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

$$I_4 = \frac{1}{16} \times \begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$

$$I_8 = \frac{1}{64} \times \begin{bmatrix} 0 & 32 & 8 & 40 & 2 & 34 & 10 & 42 \\ 48 & 16 & 56 & 24 & 50 & 18 & 58 & 26 \\ 12 & 44 & 4 & 36 & 14 & 46 & 6 & 38 \\ 60 & 28 & 52 & 20 & 62 & 30 & 54 & 22 \\ 3 & 35 & 11 & 43 & 1 & 33 & 9 & 41 \\ 51 & 19 & 59 & 27 & 49 & 17 & 57 & 25 \\ 15 & 47 & 7 & 39 & 13 & 45 & 5 & 37 \\ 63 & 31 & 55 & 23 & 61 & 29 & 53 & 21 \end{bmatrix}$$

Sample exam problem

4.2 Dithering Implementation (15 pts.)

In this problem, you will perform dithering on Figure 4.2 using a certain dithering matrix

$$T = \begin{bmatrix} 240 & 144 & 208 & 48 \\ 176 & 64 & 0 & 112 \\ 96 & 32 & 80 & 160 \\ 16 & 192 & 224 & 128 \end{bmatrix}$$

Please show your half-toned output. Note: Thresholding is for the range [0, 255].

255	255	255	255	60	60	60	60
255	255	255	255	60	60	60	60
255	255	255	255	60	60	60	60
255	255	255	255	60	60	60	60
180	180	180	180	120	120	120	120
180	180	180	180	120	120	120	120
180	180	180	180	120	120	120	120
180	180	180	180	120	120	120	120

Figure 4.2 Dithering Input

255	255	255	255	0	0	0	255
255	255	255	255	0	0	255	0
255	255	255	255	0	255	0	0
255	255	255	255	255	0	0	0
0	255	0	255	0	0	0	255
255	255	255	255	0	255	255	255
255	255	255	255	255	255	255	0
255	0	0	255	255	0	0	0

a) Show the dithering results. (6 pts.)

Sample exam problem

b) Comment on the performance of dithering matrix T. Please state your reason. (3 pts.)

The output halftoning has diagonal artifacts due to the small elements in the matrix diagonal (top right to bottom left)

c) Please design a better dithering matrix that has the same elements given in the above two threshold matrices. Please explain why yours is better. (3 pts.)

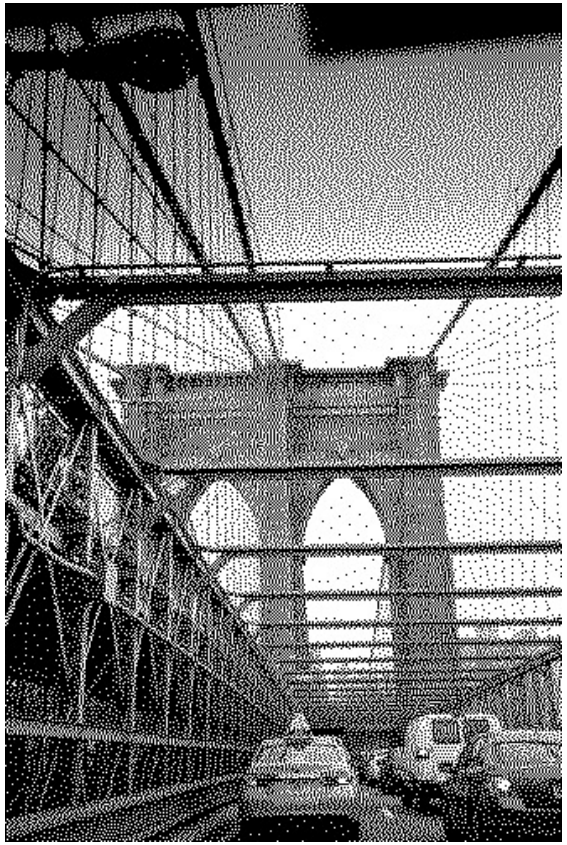
Bayer I_4 =

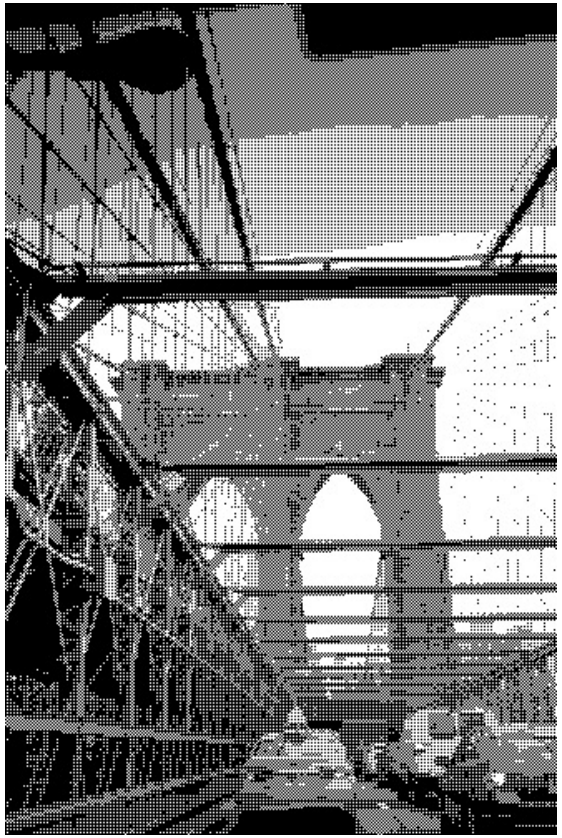
$$\begin{bmatrix} 88 & 151 & 104 & 167 \\ 215 & 24 & 231 & 40 \\ 120 & 183 & 72 & 135 \\ 247 & 56 & 199 & 8 \end{bmatrix}$$

Bayer I4 also not good! Diagonal terms small!
Should be evenly distributed to avoid small elements in one line, one column or diagonal lines

Digital halftoning

- Practice problem
  - Which is FS result, which is dithering matrix I2 result?





Left: FS
Right: I2

Color halftoning

- Color spaces:
  - RGB color space
  - CMY color space

Relationship, Application field
How to convert?

- Separable color image half-toning with error diffusion
- MBVQ with error diffusion

Difference?
Where does this difference come from?


Q
A