EE 569 Introduction to Digital Image Processing

Spring 2019

Midterm Exam 1

Name: _____

Student ID: _____

Exam Location (Please check one of the following):

- ☐ USC Campus
- ☐ Remote

Notes:

1. Permitted Time: 110 minutes
2. Open-book (textbooks, lecture notes, graded homework only)
3. Usage of computer, mobile phone, Internet is not allowed
4. Only one-line calculator is allowed
5. Grading is based on the answers written on sheets only

Problem	Point	Score
1	24	
2	25	
3	25	
4	26	
Total	100	

Problem 1: Image Demosaicing and histogram manipulation (24 pts.)

1.1 Image Demosaicing

A CFA image of size 5x5 and its associated Bayer pattern are shown in Fig. 1.1.

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

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

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)

Blue	Green
Green	Red

(b)

Figure 1.1: (a) A CFA image and (b) its associated Bayer pattern.

1.2 Contrast Histogram Manipulation

Tommy Trojan tried to enhance the contrast of the moon image as shown in Figure 1.2 with different transfer functions and produced different results. Please match each of the output images to a specific transfer function and *justify* your answer. (16 pts.)

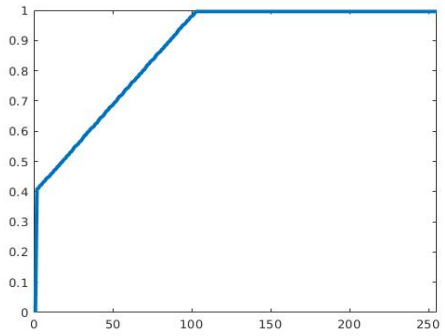
Original Moon Surface Image

Enhanced Result A

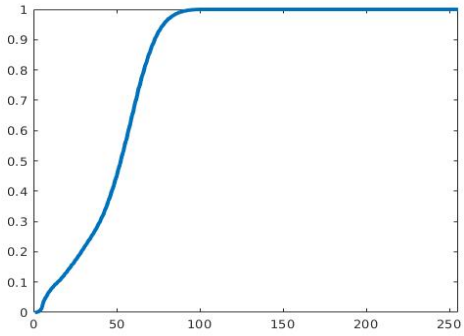
Enhanced Result B

Enhanced Result C

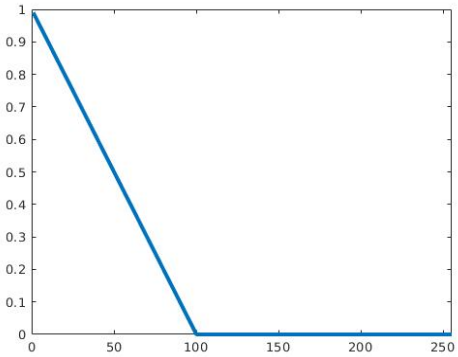
Enhanced Result D



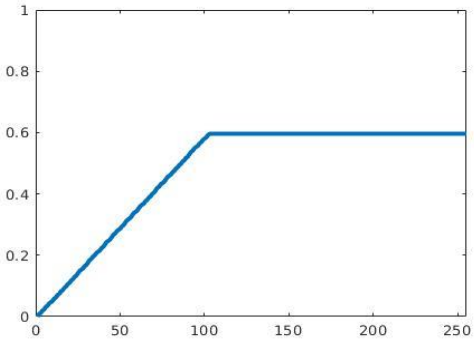
Transfer Function 1



Transfer Function 2



Transfer Function 3



Transfer Function 4

Problem 2: Image Denoising (25 pts.)

Consider an image of size 5x5 as given in Fig. 2.1. Apply your filter **ONLY** on the inner 3x3 rectangular region, you output should also be 3x3

Original Image

8	3	3	7	7
3	4	3	1	0
3	6	9	5	4
6	4	4	2	1
6	8	8	4	0

Noisy Image

9	4	4	7	7
4	3	3	1	0
3	5	8	5	5
6	3	5	2	2
5	5	6	3	1

Fig. 2.1

a) Apply a 3x3 uniform and Gaussian (with unit variance) low pass filter to this image and calculate their respective PSNR. Discuss why the difference in PSNR. (17.5 pts.)

The Gaussian kernel is

$$\mathrm{w(i,j,k,l)} = \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{(k-i)^2+(l-j)^2}{2\sigma^2}\right)$$

where σ is the variance. You can use $e^{-0.5} \approx 0.6, e^{-1} \approx 0.4$ to simplify your calculation. To save your time, you can also use the pre-computed Gaussian kernel

0.08	0.12	0.08
0.12	0.20	0.12
0.08	0.12	0.08

The PSNR value between images I and Y can be calculated as:

$$\mathrm{PSNR(dB)} = 10\log_{10}\left(\frac{\mathrm{Max}^2}{\mathrm{MSE}}\right)$$

where

$$\mathrm{MSE} = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}(Y(i,j)-I(i,j))^2$$

and where I is the noise-free image of size N × M, Y is the filtered image of size N × M, Max for 8-bit image is 255. You can leave your answer as $57.7 - 10\log_{10}(\mathrm{MSE})$

b) Apply a 3x3 median filter to the noisy image and calculate its PSNR. Discuss whether you can improve the denoising performance by using bilateral filter, why or why not? (7.5 pts.)

[This is a blank page to be used for your answer sheet]

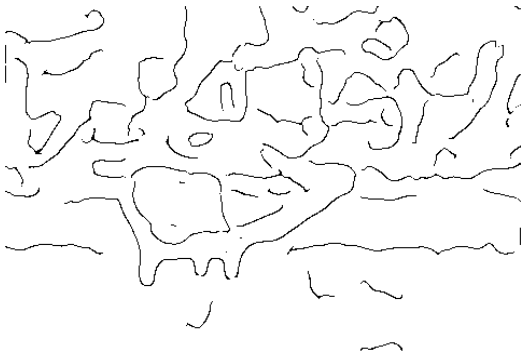
Problem 3: Edge detection (25 pts.)

a) Short questions. Answer the following questions with NO MORE THAN 3 WORDS. (4 pts.)
   a. Name the classifier used in Structured Edge.

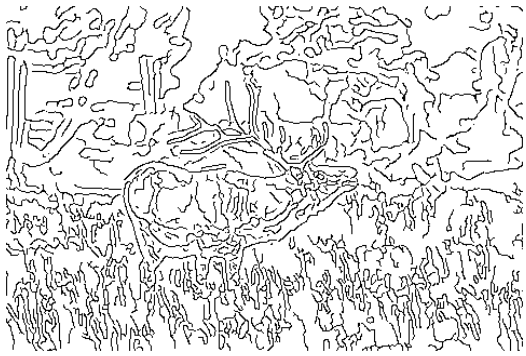
   b. How does Canny obtain thin edges?

b) Long questions.
   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.)

   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. (3 pts.)



(a)



(b)

(c)

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

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

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.)

f. Compute the gradient at the central pixel using the Sobel gradient operator (the one in **bold** font). Compute the magnitude of gradient (you can keep the square root symbol in your final answer). (4 pts.)

11	19	7	1	22
2	2	4	4	23
7	8	**6**	11	7
5	10	12	10	10
27	12	20	17	12

For your reference:

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

Gx

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

Gy

3-by-3 Sobel mask

Problem 4: Digital Halftoning (26 pts.)

4.1 Basics (10 pts.)

a) For grayscale digital halftoning, we applied 5 halftoning algorithms to Fig 4.1

1) Binarization with a fixed threshold
2) Binarization with random threshold
3) Dithering with Bayer's matrix I_2
4) Dithering with Bayer's matrix I_{16}
5) Floyd-Steinberg error diffusion

Fig 4.1 Halftoning Input Image

The obtained 5 results are presented below (next page). Please match the specific digital halftoning methods (denoted by #1, #2, #3, #4 and #5) to the output images (denoted by A, B, C, D, and E), and *justify* your answer. (5 pts.)

A

B

C

D

E

b) What's the difference and relationship between RGB and CMY color space? How can one display the Yellow color in the computer screen? How can one print one Blue dot on white paper? (5 pts.)

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

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

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

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.)

d) Is PSNR a good metric to evaluate the quality of dithered images? Please justify your answer. (3 pts.)