ECE 5273
Test 1

Thursday, March 28, 2019
4:30 PM - 5:45 PM

Spring 2019 Name: SOLUTION

Dr. Havlicek Student Num:_____

Directions: This is an open notes test. You may use the official course lecture notes and a calculator. Other materials are not allowed. You have 75 minutes to complete the test. All work must be your own.

SHOW ALL OF YOUR WORK for maximum partial credit!

GOOD LUCK!

SCORE:

1. (20) _____
2. (20) _____
3. (20) _____
4. (20) _____
5. (20) _____

_____

TOTAL (100):

_____

On my honor, I affirm that I have neither given nor received inappropriate aid in the completion of this test.

Name:_____ Date:_____

1. **20 pts.** True or False. Mark *True* only if the statement is **always** true.

TRUE	FALSE	
____	X	(a) **2 pts.** Magnetic Resonance Imaging (MRI) is a type of transmission imaging. Notes p. 1.24
____	X	(b) **2 pts.** Binary morphological erosion and dilation are inverse operations. Notes p. 2.79
____	X	(c) **2 pts.** Blob coloring is a simple method for generating the histogram of a color image. Notes p. 2.40
____	X	(d) **2 pts.** The binary OPEN filter removes small holes and gaps better than the binary MEDIAN filter, but not objects or peninsulas. Notes p. 2.88
____	X	(e) **2 pts.** The binary OPEN-CLOSE filter tends to link neighboring holes together. Notes p. 2.91
X	____	(f) **2 pts.** For a given structuring element or window, the binary Median and Majority filters are identical. Notes p. 2.80
____	X	(g) **2 pts.** The full-scale contrast stretch is an example of a geometric image operation. Notes p. 3.14
____	X	(h) **2 pts.** The 2D centered DFT is useful and intuitive because it displays the highest spatial frequencies in the center of the DFT magnitude image. Notes p. 4.70, 4.73
X	____	(i) **2 pt.** Any real-world image is approximately bandlimited. Notes p. 4.115
OH MY!		
____	____	(j) **2 pt.** There is a critical national emergency on the southern border.

2. **20 pts.** Consider the 4×4 image $\mathbf{I}$ shown below, where the allowable range of gray levels is $0 \leq I(i,j) \leq 15$:

$$\mathbf{I} = \begin{array}{|c|c|c|c|} \hline \mathbf{15} & \mathbf{14} & \mathbf{13} & \mathbf{14} \\ \hline \mathbf{10} & \mathbf{12} & \mathbf{9} & \mathbf{0} \\ \hline \mathbf{10} & \mathbf{9} & \mathbf{12} & \mathbf{10} \\ \hline \mathbf{9} & \mathbf{11} & \mathbf{15} & \mathbf{15} \\ \hline \end{array}$$

Construct a new image $\mathbf{K}$ by applying the histogram flattening algorithm to $\mathbf{I}$.

Show the new image $\mathbf{K}$ and its histogram $\mathrm{H_K}$ in the spaces provided below.

$$\mathbf{K} = \begin{array}{|c|c|c|c|} \hline 15 & 12 & 10 & 12 \\ \hline 6 & 9 & 3 & 0 \\ \hline 6 & 3 & 9 & 6 \\ \hline 3 & 7 & 15 & 15 \\ \hline \end{array}$$

k	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$\mathrm{H_K}(k)$	1	0	0	3	0	0	3	1	0	2	1	0	2	0	0	3

Work space is provided on the next page.

Workspace for Problem 2:

$I =$

15	14	13	14
10	12	9	0
10	9	12	10
9	11	15	15

$J = P_I(I) =$

16/16	13/16	11/16	13/16
7/16	10/16	4/16	1/16
7/16	4/16	10/16	7/16
4/16	8/16	16/16	16/16

For I:

k	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H(k)	1	0	0	0	0	0	0	0	0	3	3	1	2	1	2	3
p(k)	1/16	0	0	0	0	0	0	0	0	3/16	3/16	1/16	2/16	1/16	2/16	3/16
P(k)	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	4/16	7/16	8/16	10/16	11/16	13/16	16/16

For K:

k	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
H(k)	1	0	0	3	0	0	3	1	0	2	1	0	2	0	0	3
p(k)																
P(k)																

$K =$

15	12	10	12
6	9	3	0
6	3	9	6
3	7	15	15

K = FSCS(J); FSCS is given on Notes p. 3.15:

$A = \min(J) = 1/16$

$B = \max(J) = 16/16 = 1$

K = no. gray levels = 16

$K-1 = 15$

$P = \frac{K-1}{B-A} = \frac{15}{15/16} = 16$

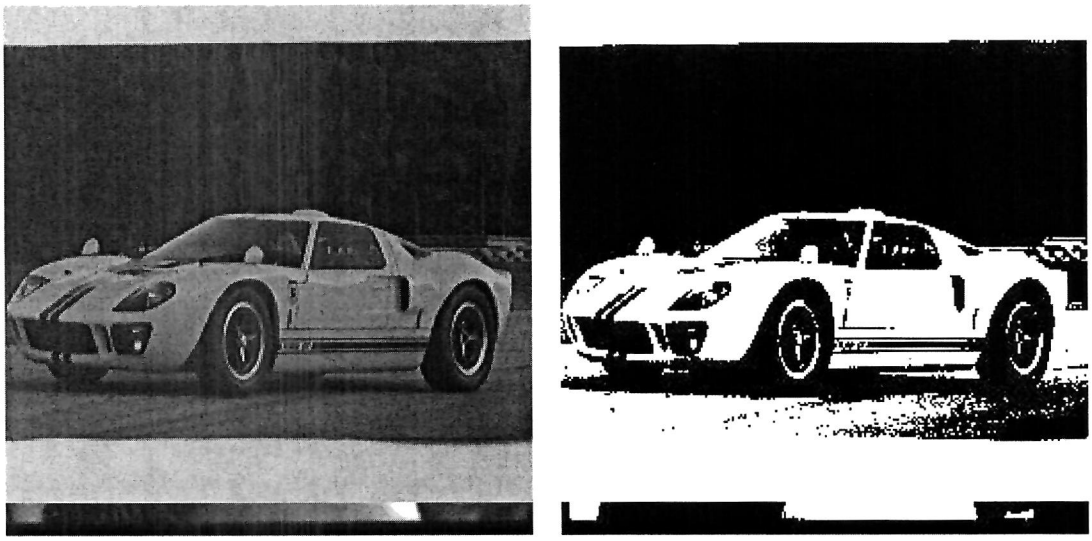
$K(m,n) = \frac{K-1}{B-A}[J(m,n) - A]$

$= 16\left[J(m,n) - \frac{1}{16}\right]$

$J(m,n)$	$K(m,n)$
1/16	0
4/16	3
7/16	6
8/16	7
10/16	9
11/16	10
13/16	12
16/16	15

3. **20 pts.** The gray scale image $\mathbf{I}_1$ shown below has 8-bit pixels. This image was thresholded to obtain the binary image $\mathbf{I}_2$, which is also shown below. In $\mathbf{I}_2$, the pixel value 255 (WHITE) represents LOGIC_ONE and the pixel value zero (BLACK) represents LOGIC_ZERO.

$\mathbf{I}_1$ $\mathbf{I}_2$



Binary morphological OPEN and CLOSE operations where performed on the image $\mathbf{I}_2$ using a 5×5 diamond-shaped structuring element. The resulting images are shown as $\mathbf{J}_1$ and $\mathbf{J}_2$ below.

$\mathbf{J}_1$ $\mathbf{J}_2$

Determine which image is the result of the OPEN operation and which is the result of the CLOSE operation. Explain your answer in the space provided on the next page.

Workspace for Problem 3...

$J_1 = \text{OPEN}(I_2)$.

- OPEN applies the erosion first. The main effects are:
  1. Large white objects are eroded by about 2 to 3 pixels, becoming smaller.
  2. Small white objects are completely eliminated.
- OPEN then applies dilation second.
  1. restores larger white objects to approximately original size.
  2. but the smaller white objects do not come back... they are permanently removed.

$\Rightarrow$ This can be seen, e.g., in the wheels and windows of the car in J_1.

$J_2 = \text{CLOSE}(I_2)$.

- CLOSE applies the dilation first. This expands all white objects by about 2 to 3 pixels. For the black objects;
  1. Larger black objects become smaller by about 2 to 3 pixels.
  2. Smaller black objects are completely eliminated.
- CLOSE then applies the erosion second.
  1. restores white objects to approximately original size.
  2. restores larger black objects to approximately original size.
  3. but the smaller black objects do not come back... they are permanently removed.

$\Rightarrow$ This can be seen, e.g., in the racing stripes and headlamps of the car in J_2.

4. **20 pts.** Consider a 6×6 digital image $\mathbf{I}$ given by

$$I(m,n) = 4 - 144\delta(m,n) + 2\cos\left[\frac{2\pi}{6}(m+2n)\right] + \sin\left[\frac{2\pi}{6}(-2m+n)\right],$$

where m = column and n = row.

(a) **10 pts.** Find a closed form expression for the DFT $\widetilde{\mathbf{I}}$.

Notes p. 4.126: $4 \overset{\text{DFT}}{\longleftrightarrow} 4(6)(6)\delta(u,v) = 144\delta(u,v)$

Notes p. 4.127: $-144\delta(m,n) \overset{\text{DFT}}{\longleftrightarrow} -144$

Notes p. 4.128: $2\cos\left[2\pi\left(\frac{1}{6}m + \frac{2}{6}n\right)\right] \overset{\text{DFT}}{\longleftrightarrow} \left(\frac{2}{2}\right)(6)(6)\left[\delta(u-1,v-2) + \delta(u+1,v+2)\right]$

$= 36\left[\delta(u-1,v-2) + \delta(u+1,v+2)\right]$

Notes p. 4.129: $\sin\left[2\pi\left(-\frac{2}{6}m + \frac{1}{6}n\right)\right] \overset{\text{DFT}}{\longleftrightarrow} j\left(\frac{1}{2}\right)(6)(6)\left[\delta(u-2,v+1) - \delta(u+2,v-1)\right]$

$= j18\left[\delta(u-2,v+1) - \delta(u+2,v-1)\right]$

$$\widetilde{I}(u,v) = 144\delta(u,v) - 144 + 36\left[\delta(u-1,v-2) + \delta(u+1,v+2)\right] + j18\left[\delta(u-2,v+1) - \delta(u+2,v-1)\right]$$

(b) **10 pts.** Show the real and imaginary parts of the **centered** DFT array in the space provided below:

$\widetilde{\mathbf{I}} =$

v \ u	-3	-2	-1	0	1	2
-3	A	A	A	A	A	A
-2	A	A	-108	A	A	A
-1	A	A	A	A	A	A
0	A	A	A	0	A	A
1	A	A	A	A	A	A
2	A	A	A	A	-108	A

$A = -144$

$+ \; j \times$

v \ u	-3	-2	-1	0	1	2
-3	0	0	0	0	0	0
-2	0	0	0	0	0	0
-1	0	0	0	0	0	18
0	0	0	0	0	0	0
1	0	-18	0	0	0	0
2	0	0	0	0	0	0

5. **20 pts.** Draw lines to match the images with their log-magnitude DFT spectra.