ECE 5273
Test 1

Tuesday, March 24, 2020
4:30 PM - 6:15 PM

Spring 2020 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.

- You have from 4:30 to 4:45 PM to print the test.
- Begin working the test at 4:45 PM.
- Stop working the test no later than 6:00 PM.
- You have until 6:15 PM to scan or photograph the test and upload to canvas.

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**. Snapping a picture with your cell phone camera is an example of absorption imaging. Notes p. 1.25
X		(b) **2 pts**. The YCbCr color space was originally used for color TV so that black and white TV's could continue to function by receiving and displaying the Y component. Notes p. 1.62
	X	(c) **2 pts**. The main reason that digital image processing is useful in so many scientific fields is that an image fully captures all of the 3D information in the camera field of view. Notes p. 1.32
	X	(d) **2 pts**. The binary Dilation and OPEN filters are dual operations with respect to complementation. Notes p. 2.77
	X	(e) **2 pts**. The binary OPEN-CLOSE filter tends to link neighboring holes together. Notes p. 2.91
	X	(f) **2 pts**. Histogram equalization is an example of a geometric image operation. Notes p. 3.65
	X	(g) **2 pts**. Plasma and LCD displays always require gamma correction. Notes p. 3.25
	X	(h) **2 pts**. The DFT of any real-valued digital image is real and even symmetric. Notes p. 4.59
X		(i) **2 pt**. The DFT of any digital image is periodic. Notes p. 4.64
OH	MY!	(j) **2 pt**. The COVID-19 virus was secretly developed by the Democrats as a way to defeat Trump in 2020.

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

I =

15	**14**	**2**	**1**
14	**15**	**2**	**1**
14	**2**	**1**	**0**
2	**1**	**0**	**0**

Construct a new image **K** by applying the histogram flattening algorithm to **I**.

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

K =

15	13	9	5
13	15	9	5
13	9	5	0
9	5	0	0

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

Work space is provided on the next page.

Workspace for Problem 2:

$$I = \begin{array}{|c|c|c|c|} \hline 15 & 14 & 2 & 1 \\ \hline 14 & 15 & 2 & 1 \\ \hline 14 & 2 & 1 & 0 \\ \hline 2 & 1 & 0 & 0 \\ \hline \end{array}$$

$$J = P_I(I) = \begin{array}{|c|c|c|c|} \hline 16/16 & 14/16 & 11/16 & 7/16 \\ \hline 14/16 & 16/16 & 11/16 & 7/16 \\ \hline 14/16 & 11/16 & 7/16 & 3/16 \\ \hline 11/16 & 7/16 & 3/16 & 3/16 \\ \hline \end{array}$$

For I :

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

For K :

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

$$K = \begin{array}{|c|c|c|c|} \hline 15 & 13 & 9 & 5 \\ \hline 13 & 15 & 9 & 5 \\ \hline 13 & 9 & 5 & 0 \\ \hline 9 & 5 & 0 & 0 \\ \hline \end{array}$$

$K = FSCS(J)$; FSCS is given on notes p. 3,15 ;

$A = \min(J) = 3/16$

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

$K =$ no. gray levels $= 16$

$K-1 = 15$

$P = \frac{K-1}{B-A} = \frac{15}{13/16} = \frac{15 \cdot 16}{13}$

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

$$= \frac{15 \cdot 16}{13}\left[J(m,n) - \tfrac{3}{16}\right]$$

$$= \frac{15}{13}\left[16 \cdot J(m,n) - 3\right]$$

$\rightarrow$ Round!

J(m,n)	K(m,n)
3/16	0
7/16	5
11/16	9
14/16	13
16/16	15

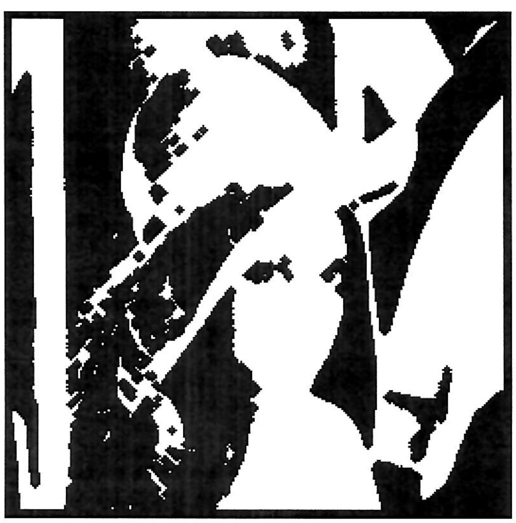
3. **20 pts**. The gray scale image $\mathbf{I}_1$ shown below has 8-bit pixels. This image was thresholded to obtain the binary image $\mathbf{I}_2$, which is also shown below. In $\mathbf{I}_2$, the pixel value 255 (WHITE) represents LOGIC_ONE and the pixel value zero (BLACK) represents LOGIC_ZERO.

$\mathbf{I}_1$

$\mathbf{I}_2$

Binary morphological OPEN and CLOSE operations were 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.

$\mathbf{J}_1$



CLOSE

$\mathbf{J}_2$

OPEN

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 is CLOSE. For CLOSE, the dilation is done first. This enlarges the fine LOGIC-ONE structure of the feather, but the mouth is lost. The subsequent erosion operation returns the structure of the feather to approximately its original size, but cannot recover the mouth.

J_2 is OPEN. For OPEN, the erosion is performed first. The mouth remains, but fine LOGIC-ONE structure of the feather is lost. The dilation is then performed second. This restores the mouth to approximately its original size. However, the fine LOGIC-ONE structure of the feather can not be restored.

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

$$I(m,n) = 3 + 12\delta(m,n) - \cos\left[\frac{2\pi}{6}(m+2n)\right] + \sin\left[\frac{2\pi}{6}(2m-n)\right],$$

where m = column and n = row.

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

Notes p. 4.126 : $3 \overset{DFT}{\longleftrightarrow} 3\cdot 6\cdot 6\cdot \delta(u,v) = 108\delta(u,v)$

Notes p. 4.127 : $12\delta(m,n) \overset{DFT}{\longleftrightarrow} 12$

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

$= -18\left[\delta(u-1,v-2)+\delta(u+1,v+2)\right]$

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

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

$$\boxed{\tilde{I}(u,v) = 108\delta(u,v) + 12 - 18\left[\delta(u-1,v-2)+\delta(u+1,v+2)\right] + j18\left[\delta(u+2,v-1) - \delta(u-2,v+1)\right]}$$

(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	12	12	12	12	12	12
-2	12	12	-6	12	12	12
-1	12	12	12	12	12	12
0	12	12	12	120	12	12
1	12	12	12	12	12	12
2	12	12	12	12	-6	12

$+ \; j \times$

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.