ECE 5273
Test 1

Tuesday, March 7, 2023
4:30 PM - 5:45 PM

Spring 2023 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) **1 pts.** Imaging sonar is an example of absorption imaging. Reflection
X		(b) **1 pts.** A binary median filter removes both gaps and peninsulas of insufficient size.
	X	(c) **1 pts.** The DFT of a real-valued digital image is real and conjugate symmetric. X → only if the image is also even symmetric
	X	(d) **1 pts.** A flat histogram usually indicates an overexposed image. Notes p. 2.25
	X	(e) **1 pts.** Run-length coding always reduces the storage requirement for a digital image. Notes p. 2.103
	X	(f) **2 pts.** To implement linear convolution of two 128 × 128 digital images by multiplying DFT's, it is generally necessary to zero pad the images to a size of 512 × 512. X
	X	(g) **2 pts.** The binary OPEN-CLOSE morphological filter tends to link neighboring holes together. Notes p. 2.91
	X	(h) **2 pts.** The full-scale contrast stretch is an example of a geometric image operation. Notes p. 3.14
X		(i) **2 pts.** For a typical digital image, logarithmic range compression is useful for displaying the DFT magnitude. Notes p. 4.61
	X	(j) **2 pts.** Frame averaging is a common technique for detecting motion in a video sequence. Notes p. 3.52
X		(k) **2 pts.** Aliasing always occurs when an optical (continuous) Gaussian image is spatially sampled to make a digital image. Notes p. 4.115, 4.120
OH MY!		(l) **3 pts.** *Top Gun* was better than *Avatar*.

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

$$\mathbf{I} = \begin{array}{|c|c|c|c|} \hline \mathbf{11} & \mathbf{8} & \mathbf{3} & \mathbf{0} \\ \hline \mathbf{9} & \mathbf{7} & \mathbf{1} & \mathbf{0} \\ \hline \mathbf{7} & \mathbf{5} & \mathbf{5} & \mathbf{1} \\ \hline \mathbf{3} & \mathbf{11} & \mathbf{13} & \mathbf{15} \\ \hline \end{array}$$

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

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

$$\mathbf{K} = \begin{array}{|c|c|c|c|} \hline 13 & 10 & 4 & 0 \\ \hline 11 & 9 & 2 & 0 \\ \hline 9 & 6 & 6 & 2 \\ \hline 4 & 13 & 14 & 15 \\ \hline \end{array}$$

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

Work space is provided on the next page.

Work is shown on the next page.

Workspace for Problem 2:

$I =$

11	8	3	0
9	7	1	0
7	5	5	1
3	11	13	15

$J =$

14/16	11/16	6/16	2/16
12/16	10/16	4/16	2/16
10/16	8/16	8/16	4/16
6/16	14/16	15/16	16/16

For I:

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

For K:

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

$K =$

13	10	4	0
11	9	2	0
9	6	6	2
4	13	14	15

$J(m,n)$	$K(m,n)$
2/16	0
4/16	2
6/16	4
8/16	6
10/16	9
11/16	10
12/16	11
14/16	13
15/16	14
16/16	15

K = FSCS(J); FSCS is given on notes P. 3.15

$A = \min(J) = 2/16$

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

$K = 2^B = 2^4 = 16$

$K - 1 = 15$ (as given)

$P = \frac{K-1}{B-A} = \frac{15}{\frac{16}{16} - \frac{2}{16}} = \frac{15}{14/16} = \frac{15 \cdot 16}{14}$

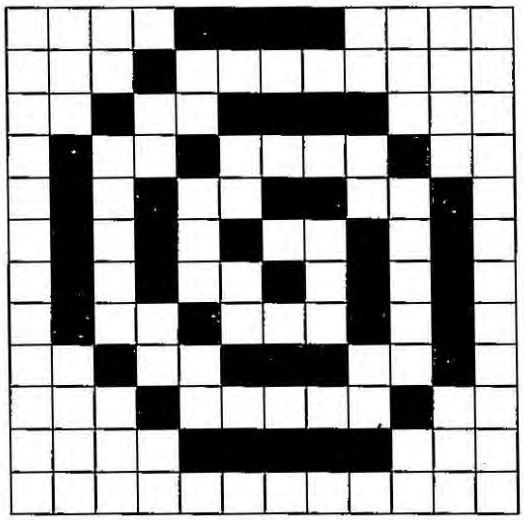
$K(m,n) = P(J(m,n) - A)$

$= \frac{15 \cdot 16}{14}\left[J(m,n) - \frac{2}{16}\right]$

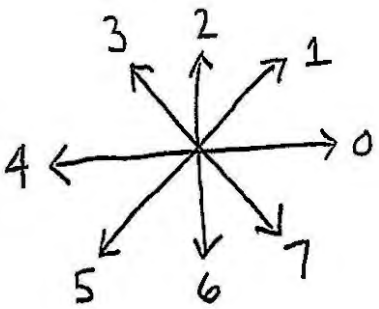
$= \frac{15}{14}\left[16J(m,n) - 2\right]$

(Round to nearest integer)

3. **20 pts.** Consider the binary contour image shown below, where white represents LOGIC_ZERO and black represents LOGIC_ONE.



NOTES p. 2.109:



(a) **12 pts.** Let the upper left pixel have coordinates (row,col) = (0,0). Give a chain code for this image. Don't forget to include the coordinates of the initial pixel and the end-of-code "flag."

SOLUTION 1: Initial pixel (row, col) = (0, 7):

(0,7) 4 4 4 5 5 5 6 6 6 7 7 7 0 0 0 0 1 1 2 2 2 2 3 3 4 4 4 5 5 6 6
7 7 0 0 1 2 2 3 4 5 7 3//
↖ FLAG

= (0,7) 100 100 100 101 101 101 110 110 110 110 111 111 111 000 000 000 000 001 001
010 010 010 010 011 011 100 100 100 101 101 110 110 111 111 000 000
001 010 010 011 100 101 111 011

SOLUTION 2: Initial pixel (row, col) = (6,6):

(6,6) 3 1 0 7 6 6 5 4 4 3 3 2 2 1 1 0 0 0 7 7 6 6 6 5 5
4 4 4 4 3 3 3 2 2 2 2 1 1 1 0 0 0 4// ← "FLAG"

= (6,6) 011 001 000 111 110 110 101 100 100 011 011 010 010 001 001
000 000 000 111 111 110 110 110 110 101 101 100 100 100 100
011 011 011 010 010 010 010 001 001 001 000 000 000 100

Workspace for Problem 3...

(b) **8 pts.** Four-conntected Blob Coloring (connected components analysis) is applied to the image with minor region removal. Show the result below.

— After blob coloring, there are 19 blobs.

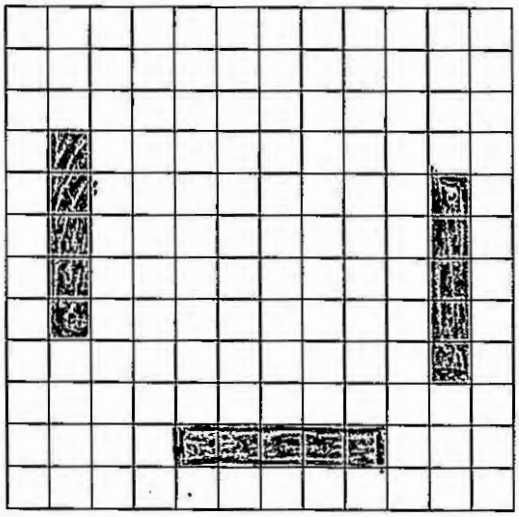
— The largest blob count is 5.

— However, there are three blobs that all have the largest count.

— ONLY ONE of these three should be retaind after minor region removal.

— Any one of the three largest blobs may be retained.

⇒ The three largest blobs are shown below; only one of them should be retained.



only one of these three blobs should be chosen as the final answer.

4. **20 pts.** Consider a 6×6 digital image I given by

$$I(m,n) = 1 + 2\cos\left[\frac{2\pi}{6}(m+2n)\right] + 2\sin\left[\frac{2\pi}{6}(2m-n)\right],$$

where m = column and n = row.

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

Notes p. 4.126: $1 \overset{DTFT}{\Longleftrightarrow} 1 \cdot 6 \cdot 6 \cdot \delta(u,v) = 36\delta(u,v)$

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

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

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

$= j36\left[\delta(u+2, v-1) - \delta(u-2, v+1)\right]$

$$\tilde{I}(u,v) = 36\delta(u,v) + 36\left[\delta(u-1, v-2) + \delta(u+1, v+2)\right] + j36\left[\delta(u+2, v-1) - \delta(u-2, v+1)\right]$$

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

$\tilde{I} =$

v \ u	-3	-2	-1	0	1	2	
	0	0	0	0	0	0	-3
	0	0	36	0	0	0	-2
	0	0	0	0	0	0	-1
	0	0	0	36	0	0	0
	0	0	0	0	0	0	1
	0	0	0	0	36	0	2

$+ \; j \times$

v \ u	-3	-2	-1	0	1	2	
	0	0	0	0	0	0	-3
	0	0	0	0	0	0	-2
	0	0	0	0	0	-36	-1
	0	0	0	0	0	0	0
	0	36	0	0	0	0	1
	0	0	0	0	0	0	2

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