ECE 5273
Test 1

Wednesday, March 12, 2003
5:00 PM - 6:15 PM

Spring 2003 — Name: SOLUTION

Dr. Havlicek — Student Num: ____________

Directions: This is an open book, open notes test. 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) ________

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TOTAL (100):

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1. **20 pts.** The connected components labeling algorithm (blob coloring algorithm) given in the notes is a *4-connected* algorithm. This means that any two LOGIC ONE pixels that are 4-neighbors will always become part of the same connected component (blob).

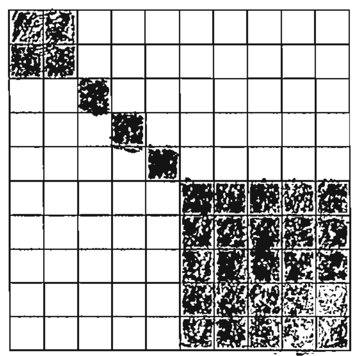
It is also possible to define an 8-connected algorithm, so that any two LOGIC ONE pixels that are 8-neighbors will always end up in the same blob.

Consider the application of connected components labeling with minor region removal. Use the blank 10×10 grid below to construct an image $\mathbb{I}$ such that the results will be different depending on whether a 4-connected or an 8-connected blob coloring algorithm is used.

Indicate LOGIC ONE pixels with the numeral "1" or by "coloring in" (shading). Indicate LOGIC ZERO pixels with the numeral "0" or by "not coloring in."

Explain your answer in the space provided below the image.

$\mathbb{I} =$



- With the 4-connected algorithm, the upper-left and lower-right squares are separate blobs (as are each of the diagonal connecting pixels). After labeling and minor region removal, only the lower-right square will remain.
- With the 8-connected algorithm, all of the LOGIC-ONE pixels in the image are part of the same blob. Since there is only one blob, the result after labeling and minor region removal will be identical to the original image.

2. **20 pts**. The gray scale image $\mathbb{I}_1$ shown below has 8-bit pixels. This image was thresholded to obtain the binary image $\mathbb{I}_2$, which is also shown below. In $\mathbb{I}_2$, the pixel value 255 (WHITE) represents LOGIC ONE and the pixel value zero (BLACK) represents LOGIC ZERO.

$\mathbb{I}_1$

$\mathbb{I}_2$

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

$\mathbb{J}_1$

$\mathbb{J}_2$

Determine which image is the result of the OPEN operation and which is the result of the CLOSE operation. Explain your answer.

$$\mathbb{J}_1 = \text{CLOSE}[\mathbb{I}_2] \text{ and } \mathbb{J}_2 = \text{OPEN}[\mathbb{I}_2].$$

This can be determined by observing, e.g., the subject's eyes and lips.

CLOSE removes holes and gaps of LOGIC ZERO pixels, but does not remove fine structure of LOGIC ONE pixels. Thus details in the eyes remain after CLOSE.

OPEN removes small objects and peninsulas of LOGIC ONE pixels, but does not remove fine structure of LOGIC ZERO pixels. Thus, the fine (LOGIC ONE) structure of the eyes is filled in with LOGIC ZERO pixels after the OPEN.

3. **20 pts.** Consider the 4×4 image $\mathbb{I}$ shown below, where the allowable range of gray levels is $0 \leq I(i,j) \leq 15$:

$\mathbb{I}$ =

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

Construct a new image $\mathbb{J}$ by applying the histogram flattening algorithm to $\mathbb{I}$. Show the new image $\mathbb{J}$ and its histogram $H_{\mathbb{J}}$ in the spaces provided below:

$\mathbb{J}$ =

15	13	10	7
13	15	10	7
13	10	7	3
10	7	3	3

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

Work Space:

$\mathbb{J}_1$ =

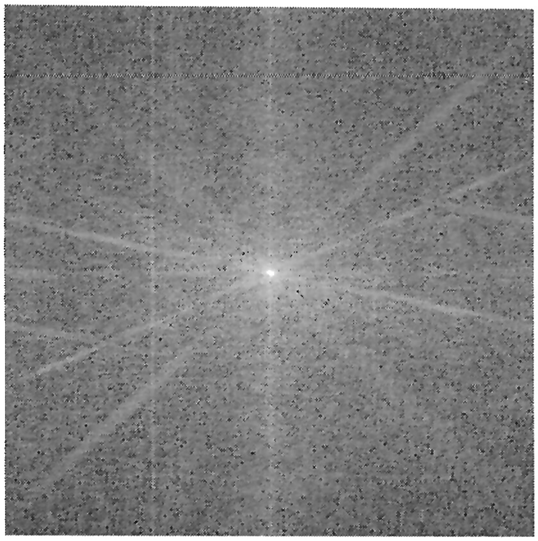
16/16	14/16	11/16	7/16
14/16	16/16	11/16	7/16
14/16	11/16	7/16	3/16
11/16	7/16	3/16	3/16

for $\mathbb{I}$:

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

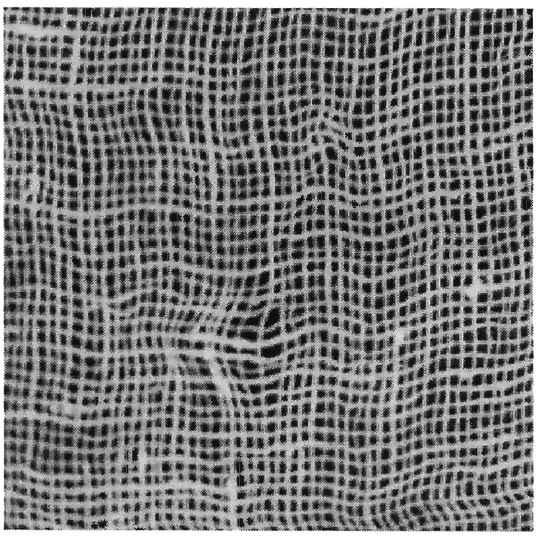
4. **20 pts**. Match the images $\mathbb{I}_1$ and $\mathbb{I}_2$ shown below with their centered log-magnitude DFT's $\tilde{\mathbb{I}}_3$ and $\tilde{\mathbb{I}}_4$, which are also shown below.

$\tilde{\mathbb{I}}_3$

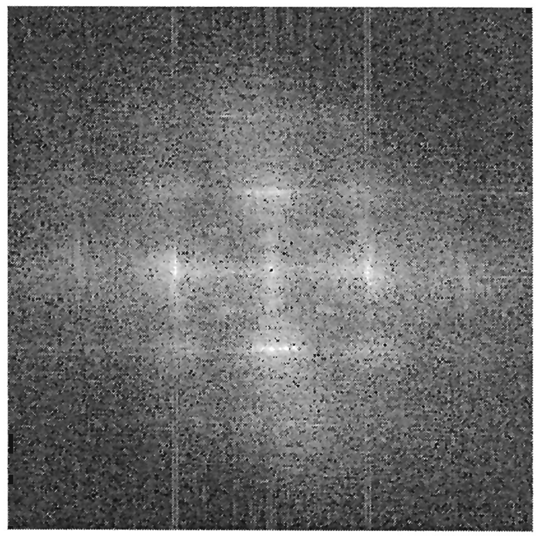


$\mathbb{I}_1$

$\mathbb{I}_2$



$\tilde{\mathbb{I}}_4$



(a) **10 pts**. DFT[$\mathbb{I}_1$] = $\tilde{\mathbb{I}}_3$ (strong diagonal structure)

(b) **10 pts**. DFT[$\mathbb{I}_2$] = $\tilde{\mathbb{I}}_4$ (predominant structure is horizontal and vertical)

5. **20 pts.** A continuous optical image $I_C(x, y)$ is incident on the focal plane of an ideal pinhole digital camera. The image $I_C(x, y)$ is a Gaussian and is given by

$$I_C(x, y) = \exp\left[-\left(x^2 + y^2\right)/\sigma^2\right],$$

where the spatial coordinates x and y are in units of meters and where $\sigma = 90 \times 10^{-3}$ meters.

The camera obtains a digital image $I(i, j)$ by sampling $I_C(x, y)$ according to $I(i, j) = I_C(iX, jY)$, where the horizontal and vertical sample spacings are given by $X = Y = 30 \times 10^{-6}$ meters. Is this spatial sampling sufficient to prevent distortion of the digital image due to aliasing?

- The continuous image I_C is a Gaussian.
- So its continuous Fourier transform $\tilde{I}_C$ is also a Gaussian. This means that $\tilde{I}_C$ is nonzero for all values of ω_x and ω_y.
- Then the continuous image is not bandlimited and $\Omega_x, \Omega_y \to \infty$.

$\Rightarrow$ Distortion due to aliasing will occur no matter what size the pixels are.

The sampling is not sufficient