ECE 5273
Test 1

Wednesday, April 1, 2009
4:30 PM - 5:45 PM

Spring 2009 Name: SOLUTION

Dr. Havlicek Student Num:________________

Directions: This is an open book, open notes test. 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. (25) ________

2. (25) ________

3. (25) ________

4. (25) ________

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

TRUE	FALSE	
___	✓	(a) **2 pt**. Medical X-Rays are an example of emission imaging.
___	✓	(b) **2 pts**. For viewing the DFT of an image $\mathbb{I}$ with real-valued pixels, it is usually most useful to display the logarithm of the DFT phase.
___	✓	(c) **2 pts**. Thresholding is usually an effective technique for separating the object and background in any image $\mathbb{I}$, provided that the histogram $H_{\mathbb{I}}(k)$ is multi-modal.
✓	___	(d) **2 pt**. For binary images, OPEN and CLOSE are dual operations with respect to complementation, *i.e.*, NOT[OPEN($\mathbb{I}$,$\mathbb{B}$)] = CLOSE[NOT($\mathbb{I}$),$\mathbb{B}$].
___	✓	(e) **2 pts**. Erosion is a morphological operation that removes holes of sufficiently small size.
___	✓	(f) **2 pts**. Erosion is a morphological operation that removes gaps or bays of insufficient width.
___	✓	(g) **2 pts**. Any image $\mathbb{I}$ can be exactly reconstructed from its histogram $H_{\mathbb{I}}(k)$.
✓	___	(h) **2 pts**. Any 8×8 digital image can be written uniquely as a sum of 64 8×8 complex exponential images.
___	✓	(i) **2 pts**. In the framework of binary morphological filtering, the median filter may be interpreted as an asymmetric smoother because it tends to remove holes that are too small while preserving objects (potatoes) of any size.
✓	___	(j) **2 pts**. The full-scale contrast stretch is an example of a linear point operation.
___	✓	(k) **2 pts**. Any real-valued digital image $\mathbb{I}$ has a DFT $\tilde{\mathbb{I}}$ that is real-valued and conjugate symmetric.
___	✓	(l) **3 pts**. The famous *Lena* image originally appeared in the magazine *Better Homes and Gardens*.

2. **25 pts**. A 3D scene consisting of a black square against a white background is imaged with a pinhole camera having a focal length of 35mm. The 3D space coordinates (X,Y,Z) of the four corners of the rectangle in units of meters are

$$
\begin{aligned}
P_1 &= (2.0000 \text{ m}, 3.4641 \text{ m}, 7.0000 \text{ m}), \\
P_2 &= (2.0698 \text{ m}, 5.4638 \text{ m}, 3.5364 \text{ m}), \\
P_3 &= (2.0698 \text{ m}, 1.9997 \text{ m}, 1.5364 \text{ m}), \text{ and} \\
P_4 &= (2.0000 \text{ m}, 0.0000 \text{ m}, 5.0000 \text{ m}).
\end{aligned}
$$

Find the projections of the four corners in the image plane and carefully sketch the image that is obtained.

$$(x,y) = \frac{f}{Z}(X,Y)$$

P1: $(x,y) = \frac{0.0350}{7.0000}(2.0000, 3.4641) = (0.0100, 0.0173)$

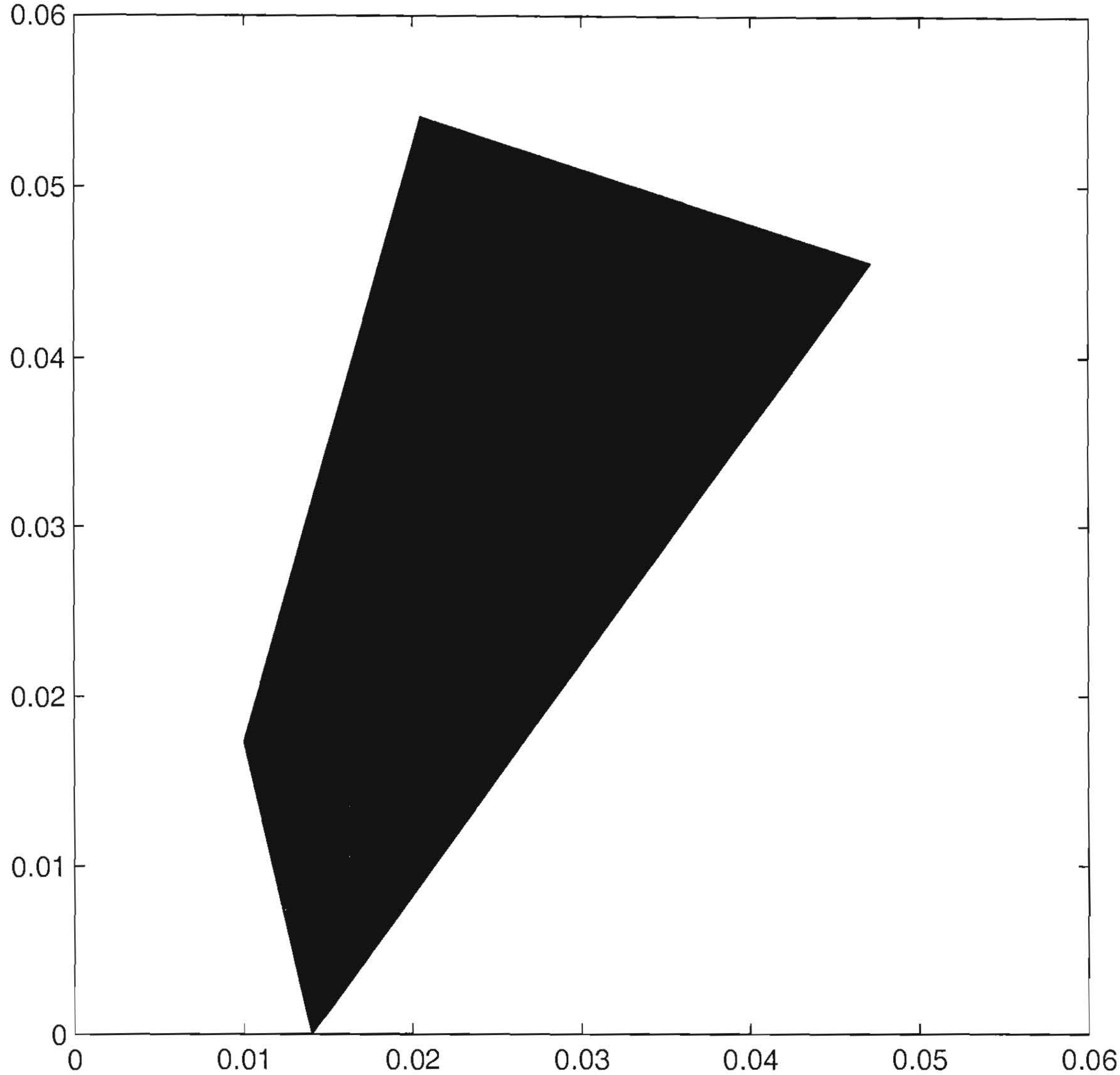
P2: $(x,y) = \frac{0.0350}{3.5364}(2.0698, 5.4638) = (0.0205, 0.0541)$

P3: $(x,y) = \frac{0.0350}{1.5364}(2.0698, 1.9997) = (0.0472, 0.0456)$

P4: $(x,y) = \frac{0.0350}{5.0000}(2.0000, 0.0000) = (0.0140, 0.0000)$

→

More Workspace for Problem 2...



3. **25 pts**. Consider the 4×4 images $\mathbb{I}$ and $\mathbb{I}'$ shown below, where the allowable range of gray levels is $0 \leq I(i,j), I'(i,j) \leq 15$:

$\mathbb{I}$ =

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

$\mathbb{I}'$ =

14	**11**	**5**	**8**
14	**2**	**8**	**8**
14	**5**	**14**	**11**
14	**14**	**11**	**11**

Construct a new image $\mathbb{J}$ by applying the histogram matching algorithm to shape the histogram of image $\mathbb{I}$, where the desired shape is given by the histogram of the image $\mathbb{I}'$. Show the new image $\mathbb{J}$ and its histogram $H_{\mathbb{J}}$ in the spaces provided below. Work space is given on the next page.

$\mathbb{J}$ =

14	14	8	5
14	11	8	5
11	11	11	8
8	14	14	14

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

Workspace for Problem 3...

Work Space:

$\mathbb{J}_1$

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	16/16	16/16

14	14	8	5
14	11	8	5
11	11	11	8
8	14	14	14

$= \mathbb{J}$

Histogram of $\mathbb{I}$

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	2	0	0
$p(k)$	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	2/16	0/16	0/16

Histogram of $\mathbb{I}'$

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

n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$P'(n)$	0/16	0/16	1/16	1/16	1/16	3/16	3/16	3/16	6/16	6/16	6/16	10/16	10/16	10/16	16/16	16/16

$$J_1(i,j) = \sum_{k=0}^{I(i,j)} p(k) \; ; \quad J(i,j) = \arg\min_n \left\{ P'(n) \geq J_1(i,j) \right\}$$

$I(i,j)$	$J_1(i,j)$	min $P'(n)$ s.t. $P'(n) \geq J_1(i,j)$	$n = J(i,j)$
0	2/16	3/16	5
1	4/16	6/16	8
2	4/16	6/16	8
3	6/16	6/16	8
4	6/16	6/16	8
5	8/16	10/16	11
6	8/16	10/16	11
7	10/16	10/16	11
8	11/16	16/16	14
9	12/16	16/16	14
10	12/16	16/16	14
11	14/16	16/16	14
12	14/16	16/16	14
13	16/16	16/16	14

4. **25 pts.** Draw lines to match the images with their log-magnitude DFT spectra.