ECE 5273
Test 2

Wednesday, May 11, 2016
10:30 AM - 12:30 PM

Spring 2016 Name: SOLUTION

Dr. Havlicek Student Num:

Directions: This is an open notes test. You may use a clean copy of the course notes as published on the course web site. Other materials are not allowed. You have 120 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.** The most computationally efficient way to compute the linear convolution of two images is to take their 2D DFT's and multiply them pointwise. you must zero pad
	X	(b) **2 pts.** Median filtering of a 512 × 512 digital image can be efficiently implemented by multiplying DFT's. It's a nonlinear filter
X		(c) **2 pts.** The binary version of any stack filter is a positive boolean function. Notes p. 6.50
	X	(d) **2 pts.** Since it belongs to both classes, the trimmed mean filter can be treated as an order statistic filters or as a linear filter. True for the mean filter, but trimmed mean is nonlinear
X		(e) **2 pts.** In the linear image restoration problem, the Wiener filter reduces to the inverse filter if no additive noise is present. Notes p. 5.129
	X	(f) **2 pts.** The pseudo-inverse filter is the best choice for restoring a digital image that has been corrupted by additive white noise. It can only fix the blur. Terrible for noise. Notes p. 5.127
X		(g) **2 pts.** Homomorphic filtering can be used to transform a multiplicative noise problem into an additive noise problem. Notes p. 6.118
	X	(h) **2 pts.** Edge thinning and edge linking are usually required after application of the LoG edge detector. Notes p. 8.85
	X	(i) **2 pts.** Contour coding is an integral part of the JPEG image compression standard.
OH MY		(j) **2 pts.** Trump will be president of the United States.

2. **20 pts.** Consider the 1D "image" (signal) $\mathbf{I} = [3\ 2\ 4\ 1\ 3]$. Thus, $I(0) = 3$, $I(1) = 2$, $\ldots I(4) = 3$. This image has **three**-bit pixels.

(a) **6 pts.** Apply a three-point gray scale morphological EROSION to **I** to obtain the result $\mathbf{J} = \text{ERODE}[\mathbf{I}, \text{ROW}(3)]$. Handle edge effects by replication. Show the result "image" **J**.

I = 3 | 3 2 4 1 3 | 3

EROSION = MIN

J = [2 2 1 1 1]

(b) **14 pts.** Now obtain the same result by implementing the EROSION filter as a stack filter. **Hint:** compute the binary signals that make up the threshold decomposition of **I**, apply a binary EROSION filter to each threshold signal, and then combine the results using the stacking property to get the final gray scale answer.

	3	3	2	4	1	3	3
≥ 4	0	0	0	1	0	0	0
≥ 3	1	1	0	1	0	1	1
≥ 2	1	1	1	1	0	1	1
≥ 1	1	1	1	1	1	1	1

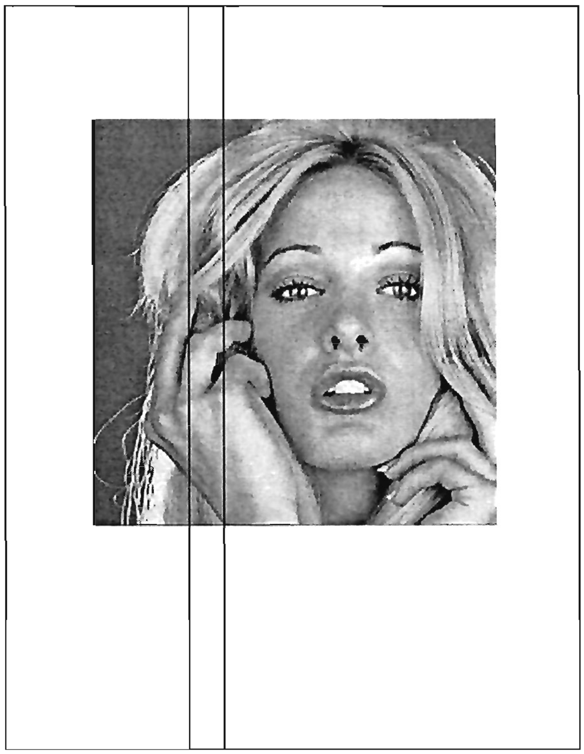
→ Binary Erosion →

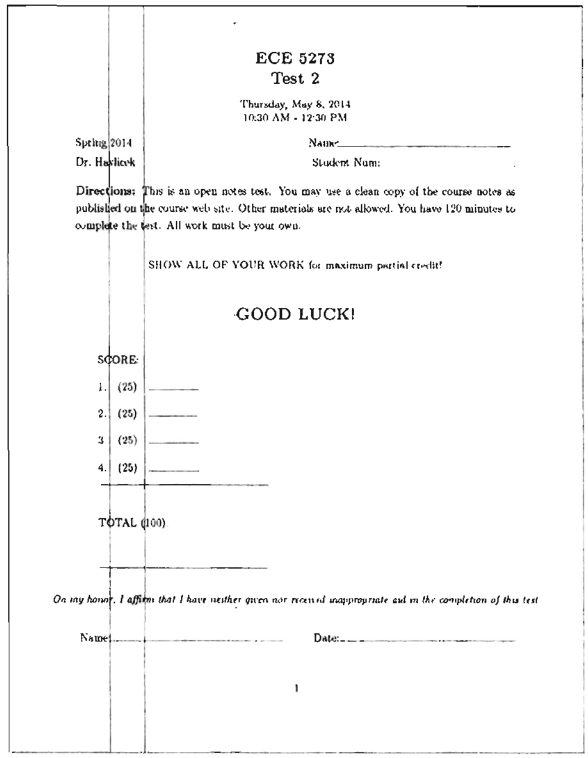
0	0	0	0	0
0	0	0	0	0
1	1	0	0	0
1	1	1	1	1

2 2 1 1 1

J = [2 2 1 1 1]

3. **20 pts**. The ECE department photocopier has developed a problem. There are vertical black lines on all of the copies. The lines are always one pixel wide and are always separated by at least 64 columns. Because it is a hardware problem, these same vertical black lines show up when the photocopier is used to make scans as well. Two examples are given below:





ECE 5273
Test 2

Thursday, May 8, 2014
10:30 AM - 12:30 PM

Spring 2014 Name____________________

Dr. Havlicek Student Num:

Directions: This is an open notes test. You may use a clean copy of the course notes as published on the course web site. Other materials are not allowed. You have 120 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:______________

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Unfortunately, it will be at least three weeks before a technician can come out to repair the problem. In the meantime, here is the plan: instead of copying, everybody will use the photocopier to scan instead. A nonlinear digital gray scale filter will then be applied to remove the vertical black lines from the scanned images, which can then be printed.

Because of your excellent performance in ECE 5273, you have been asked to design the filter. Carefully explain which filtering operation you recommend, which window or structuring element, and the reasons for your choices.

The window should be as small as possible to avoid making unnecessary changes to the good pixels.
Since the bad lines are always vertical, always one pixel wide, and always separated by at least 64 colums, the window should be a ROW.

- ROW(3) is the smallest window that will work.

As can be seen in the example images, the bad black lines will generally cross both dark and light structure in the image. MEDIAN will replace the bad pixels with a value that is similar to the majority of the pixels in the neighborhood and it will not blur edges.

⇒ Use MEDIAN with window B = ROW(3).

CLOSE would also work, but it is not as good as MEDIAN because it requires two filtering operations. So the effective overall window would be ROW(5) and it would make more changes to the good pixels.

4. **20 pts.** For the window (structuring element) SQUARE(9), give the order statistic (OS) filter weights (coefficients) $\mathbf{A}^T$ for

(a) **4 pts.** A median filter:

$$\mathbf{A}^T = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

(b) **4 pts.** An average filter:

$$\mathbf{A}^T = \begin{bmatrix} \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \end{bmatrix}$$

(c) **4 pts.** An OS filter to perform morphological erosion:

$$\mathbf{A}^T = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

(d) **4 pts.** An OS filter to perform morphological dilation:

$$\mathbf{A}^T = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

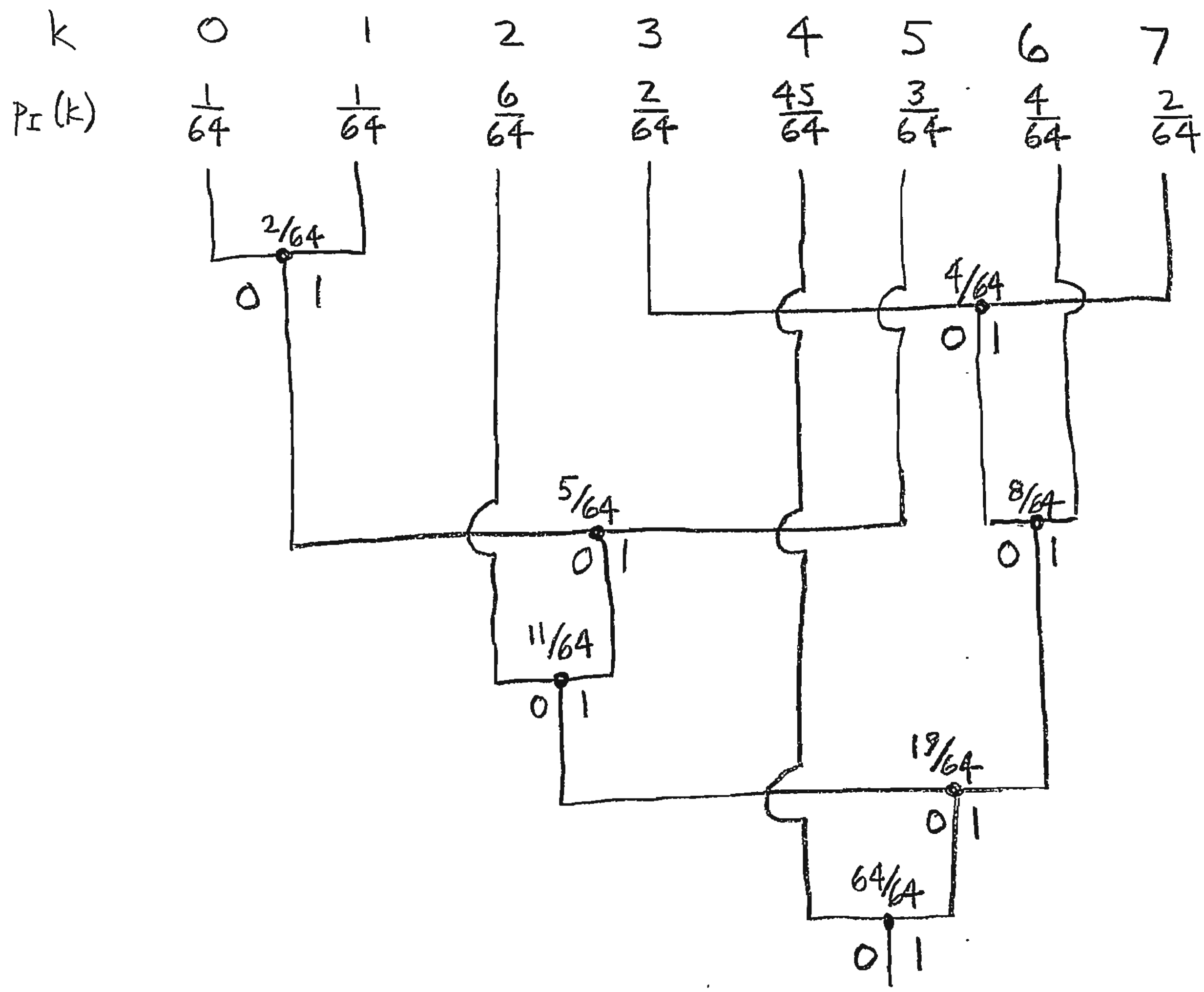
(e) **4 pts.** The trimmed mean OS filter TM_4 with Q = 2: .

$$\mathbf{A}^T = \begin{bmatrix} 0 & 0 & \frac{1}{5} & \frac{1}{5} & \frac{1}{5} & \frac{1}{5} & \frac{1}{5} & 0 & 0 \end{bmatrix}$$

5. **20 pts.** Gray scale digital images **I** with 3 bits per pixel and gray levels in the range $\{0, 1, \ldots, 7\}$ are modeled as coming from an information source with the following source symbol probabilities (normalized histogram):

k	0	1	2	3	4	5	6	7
$p_{\mathbf{I}}(k)$	$\frac{1}{64}$	$\frac{1}{64}$	$\frac{6}{64}$	$\frac{2}{64}$	$\frac{45}{64}$	$\frac{3}{64}$	$\frac{4}{64}$	$\frac{2}{64}$

(a) **12 pts.** Design a Huffman code to encode these images.



k	0	1	2	3	4	5	6	7
$C(k)$	10100	10101	100	1100	0	1011	111	1101
$L[C(k)]$	5	5	3	4	1	4	3	4

Problem 5 cont...

(b) **4 pts**. Find the expected BPP (bits per pixel) and CR (compression ratio) for the coded images $C(\mathbf{I})$.

$$\mathrm{BPP}(\hat{I}) = \sum_{k=0}^{7} p_I(k)\, L[c(k)]$$

$$= \left(\tfrac{1}{64}\right)(5) + \left(\tfrac{1}{64}\right)(5) + \tfrac{6}{64}(3) + \tfrac{2}{64}(4) + \tfrac{45}{64}(1) + \tfrac{3}{64}(4) + \tfrac{4}{64}(3) + \tfrac{2}{64}(4)$$

$$= \tfrac{1}{64}[5+5+18+8+45+12+12+8]$$

$$= \tfrac{1}{64}[113] = \frac{113}{64} \approx \underline{\underline{1.7656}} \quad (\mathrm{BPP})$$

$$\mathrm{CR} = \frac{\mathrm{BPP}(I)}{\mathrm{BPP}(\hat{I})} = \frac{3}{\frac{113}{64}} = \frac{3 \cdot 64}{113} = \frac{192}{113} \approx \underline{\underline{1.6991}}$$

(c) **4 pts.** Does your code achieve the theoretical lower bound on BPP for the coded images? Explain why or why not.

<u>NO</u>, because some of the symbol probabilities are not integer powers of 2.

For example, $p_I(4) = \frac{45}{64}$, which is not an integer power of 2.