ECE 5273
Test 2

Wednesday, April 28, 2004
5:00 PM - 6:05 PM

Spring 2004 Name: SOLUTION

Dr. Havlicek Student Num: ____________

Directions: This is an open notes, open book test. You have 65 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) ________

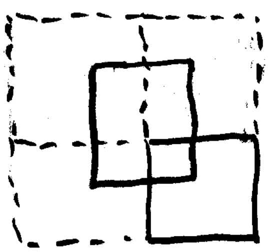
TOTAL (100):

1. **25 pts.** True or False. Mark *True* only if the statement is **always** true.

TRUE	FALSE	
	X	(a) **3 pts.** Consider implementing a 7×7 linear average filter by multiplication of DFT's. The result is $\mathbb{J} = \mathbb{I} * \mathbb{G}$, where $\mathbb{I}$ is the input image and $\mathbb{G}$ is the filter impulse response. To ensure that the DFT $\widetilde{\mathbb{G}}$ has the correct phase, it is essential to make the impulse response image $\mathbb{G}$ all zero except for the upper left block of 7×7 pixels, which should all be equal to $\frac{1}{49}$.
	X	(b) **3 pts.** The frequency response of the median filter has a low-pass characteristic; *e.g.*, the frequency response tends to pass low spatial frequencies and attenuate high spatial frequencies.
	X	(c) **3 pts.** Any gray scale morphological filter can be implemented by pointwise multiplication of DFT's.
X		(d) **2 pts.** The gradient-based edge detectors are generally less sensitive to noise than the Laplacian-type edge detectors.
	X	(e) **2 pts.** The gradient-based edge detectors are generally less sensitive to noise than the local estimator-based edge detectors.
X		(h) **2 pts.** One disadvantage of gradient-based edge detectors is that they usually depend on a threshold that must be selected empirically.
	X	(i) **2 pts.** One disadvantage of the Laplacian-type edge detectors is that the Laplacian operation is inherently directional, *i.e.*, it is a directional operator.
X		(j) **2 pts.** A major problem with watershed algorithms is that they tend to oversegment the image.
	X	(k) **2 pts.** The main advantage of anisotropic diffusion is that it is very efficient to implement; it is characterized by a very fast run time.
	X	(l) **4 pts.** The *lena* image originally appeared in the magazine *Southern Living*.

2. **25 pts.** Short Answer.

(a) **5 pts.** Consider computing the linear convolution $\mathbb{J} = \mathbb{I} * \mathbb{G}$, where $\mathbb{I}$ is the 256×256 gray scale input image and $\mathbb{G}$ is the impulse response of a 256×256 digital Gaussian filter. What is number of multiply-add operations required to compute $\mathbb{J}$ by directly convolving the images in the spatial (image) domain? For the "edge condition", assume that the image $\mathbb{I}$ is extended by zero padding to handle incomplete neighborhoods. Multiplications by these extended zero pixels are counted in the total.



Each pixel of the result $\mathbb{J}$ requires 256^2 multiply-adds.

There are 256^2 pixels in $\mathbb{J}$.

$$\text{Total} = (256^2)(256^2) = \underline{\underline{256^4}}$$
$$= 2^{32} = 4,294,967,296.$$

(b) **5 pts.** Now the image $\mathbb{J}$ from part (a) will be computed by pointwise multiplying DFT's. Note that this requires zero padding $\mathbb{I}$ and $\mathbb{G}$. How many multiply-add operations are required to compute both DFT's, multiply them pointwise, and obtain the answer $\mathbb{J}$ by inverse DFT?

① Two 512x512 FFT's: $2(512)^2 \log_2 (512)^2$
$$= 2 \cdot 2^{18} \log_2 2^{18} = 2^{19} \cdot 18 = 2^{18} \cdot 36$$

② 512x512 multiplies $= 2^{18}$

③ One 512x512 inverse FFT: $(512)^2 \log_2 (512)^2$
$$= 2^{18} \log_2 2^{18} = 18 \cdot 2^{18}$$

TOTAL = ① + ② + ③ $= 2^{18} + 18 \cdot 2^{18} + 36 \cdot 2^{18}$
$$= 55 \cdot 2^{18} = \underline{\underline{14,417,920}}$$

Problem 2, cont...

(c) **5 pts.** We often say that template matching is not a robust technique. Explain why template matching often fails unless the exact imaging geometry and lighting conditions can be precisely controlled.

To work, template matching needs a nearly perfect match between the template and the image. If we don't have precise control over the imaging geometry and the lighting, template matching is prone to fail as a result of rotation, scaling, occlusion, shading, and/or perspective distortion differences between the template and the image.

(d) **5 pts.** Briefly explain why the gray scale morphological ERODE and DILATE operations are only approximate inverses of one another.

Suppose the image contains a large circular object with a peninsula: . ERODE will shrink the object and remove the peninsula: . DILATE will restore the basic object to its original size, but the peninsula will not be restored: .

(e) **5 pts.** $\mathbb{I}$ is a constant image corrupted by additive white Laplacian noise with variance $\sigma_{\mathrm{N}}^2 = 165$. The corrupted image is filtered with a 5×5 median filter. What is the approximate variance $\sigma_{\text{filtered}}^2$ of the filtered image?

$$\sigma^2_{\text{filtered}} = \frac{\sigma^2_{IN}}{2(2M+1)} = \frac{165}{2(25)} = \underline{\underline{3.3}}$$

3. **25 pts**. Consider the 1D "image" (signal) $\mathbb{I} = [3\ 1\ 4\ 1\ 3]$. Thus, $I(0) = 3$, $I(1) = 1$, $\ldots$ $I(4) = 3$. This image has **three** bit pixels.

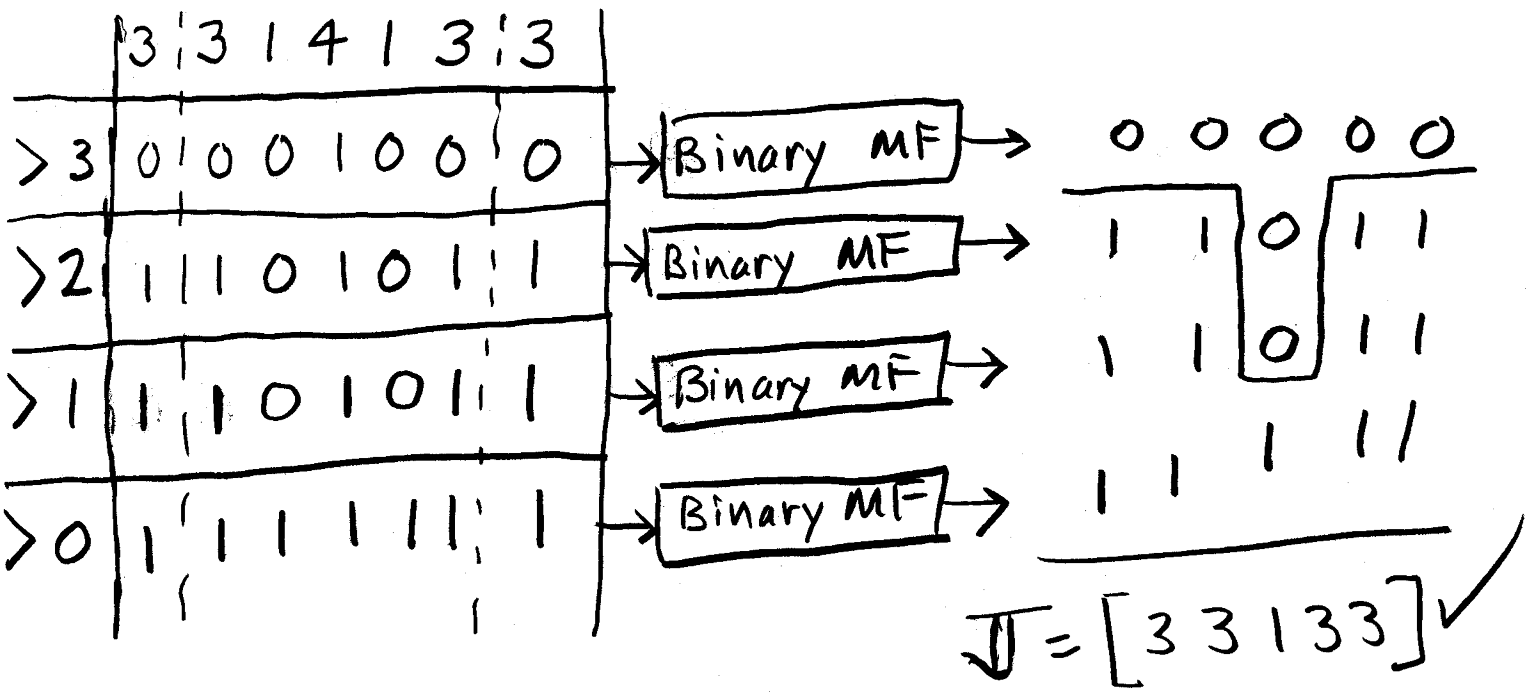
(a) **10 pts.** Apply a three-point median filter to $\mathbb{I}$ to obtain the result $\mathbb{J} = \text{MED}[\mathbb{I}, \text{ROW}(3)]$. Handle edge effects by replication. Show the result "image" $\mathbb{J}$.

$\mathbb{I}$

3 | 3 1 4 1 3 | 3

$\mathbb{J}$ = [3 3 1 3 3]

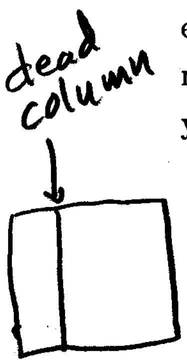
(b) **5 pts.** Now obtain the same result by implementing the median filter as a stack filter. **Hint:** compute the four binary signals that make up the threshold decomposition of $\mathbb{I}$, apply a binary median filter to each threshold signal, and combine the results using the stacking property.



4. **25 pts.** The Blowfish Digital Photographic Services Corporation makes money by scanning customer photographs to convert them into gray scale digital images. The scanner contains a linear array sensor with 5100 detectors (pixels) per inch. Thus a 'snapshot' from this sensor produces one ROW of the digital image. The sensor is mechanically scanned from top to bottom while taking successive 'snapshots' to form the entire scanned digital image.

   Unfortunately, the 1026'th detector burned out recently. The result is that this failed detector always outputs the minimum pixel value, which is zero. Therefore, the 1026'th column of every digital image obtained from this scanner is all zeros. Because it would be too expensive to replace the scanner, you have been hired to fix the problem with digital image processing.

   You can think of this as a noise removal problem, where the black column of dead pixels is considered to be due to additive noise. Design a gray scale morphological filter to enhance the scanned digital images by reducing this noise. Be sure to indicate which morphological operation you recommend as well as the structuring element. Explain your answer.



Median or CLOSE will fill in the dead column if the structuring element ROW(3) = ☐☐☐ is used. Between these two choices, median is better because:

① Median will do less changing of the other non-dead pixels. This is because CLOSE(I, B) = ERODE(DILATE(I,B),B), so that CLOSE has an effective spatial extent equal to ROW(5), whereas the the spatial extent of MED(I, B) is only that of ROW(3).

② For the same reason, CLOSE is slower than Median.

⇒ USE MEDIAN FILTER WITH STRUCTURING ELEMENT ROW(3).