NAME: ____

Computer Vision	**Prof. Rajesh Rao** **TA: Jiun-Hung Chen**
CSE 455	**Winter 2009**

Sample Final Exam

(based on previous CSE 455 exams by Profs. Seitz and Shapiro)

<u>Directions</u>

Write your name at the top of <u>every page</u>.

Start only when you are the given the "green signal".

Make sure you have 8 pages (and none are blank).

Please provide answers to the questions in the space provided, or on the back of the page.

This exam is closed book/notes except for one 8 1/2'' x 11'' review sheet.

NAME: ____

Problem 1: Short answer

For each of the following, **explain** how it may be used to help solve a computer vision problem (and specify the problem).

1. K-means

[For solution, see Segmentation lecture]

2. Principal components

[For solution, see Object Recognition lecture]

3. Sum-of-squared distances (SSD)

[For solution, see, e.g, Features lecture]

4. Epipolar lines

[For solution, see Stereo lecture]

5. Image pyramid

[For solution, see, e.g., Motion lecture]

NAME: ____

Problem 2: Filters

Part 1. Consider the 1D image below:

a	b	c	**d**	e	f	g

Image I

a) Suppose we apply a width-3 mean filter TWICE to this image. In other words, we apply a width-3 mean filter to **I** to produce a smoothed image **J**, and then re-apply the same width-3 mean to **J**. Give the expression for the center pixel after both filters have been applied.

b) Define a single 1D kernel that, when applied only once to the image, will produce the same results as applying the 1D width-3 mean filter twice. Specify your filter in the boxes below

Kernel

c) Convolutions are *associative*, meaning that if H_1 and H_2 are filters and F is an image, then

$H_1 * (H_2 * F) = (H_1 * H_2) * F$

Let's test this out with our mean filter example. Try applying a width-3 mean to the mean filter image below and specify the result below (give the center 5 pixels values).

0	0	1/3	1/3	1/3	0	0

Mean filter image

0						0

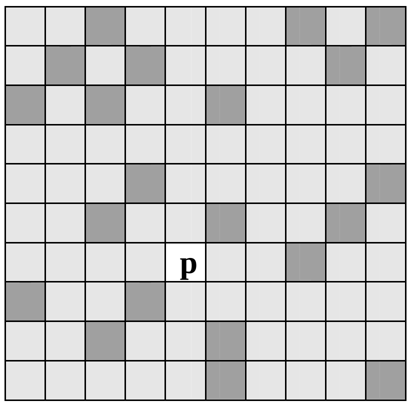
Result

[Solution: Read Image Processing lecture slides]

NAME: ____

Problem 3: Texture Synthesis

Given the two color image below, the goal of this problem is to determine the most likely value of the pixel labeled **p**.



Part A

(i) Outline the 3x3 windows in the image above that exactly match the neighborhood of **p** (there should be 5 total, not including the one centered at **p**).

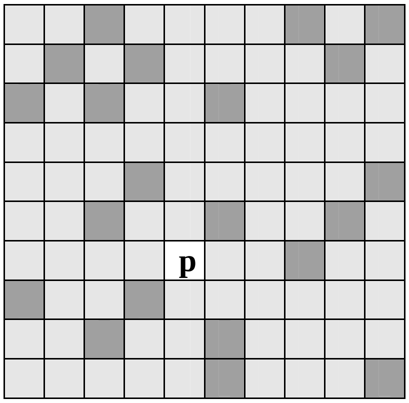
(ii) Compute the probability of **p** being each color:

P(**p** is dark pixel | 3x3Neighborhood(**p**)) = _________

P(**p** is light pixel | 3x3Neighborhood(**p**)) = _________

NAME: ____

Part B



(iii) Now consider a 5x5 neighborhood of pixels.
Outline the areas that match now.

(iv) What are the probabilities for the pixel color given the 5x5 neighborhoods?

P(**p** is dark pixel | 5x5Neighborhood(**p**)) = __________

P(**p** is light pixel | 5x5Neighborhood(**p**)) = __________

Part C

How does increasing the size of the neighborhood affect the texture synthesis results?

[Solution: Read Texture lecture slides]

NAME: ____

Problem 4: Dilation and Erosion

Let H[u,v] be a 3x3 matrix. Recall the definitions of
Erosion:
G[x,y] = 1 if F[x+u-1,y+v-1] is 1 everywhere that H[u,v] is 1
G[x,y] = 0 otherwise

Dilation:
G[x,y] = 1 if F[x+u-1,y+v-1] is 1 somewhere that H[u,v] is 1
G[x,y] = 0 otherwise

		1		1						
		1	1	1			1	1	1	
		1	1	1	1	1	1	1	1	
	1	1	1	1			1	1	1	
		1		1						

Input image F

		1	1	1			1	1	1	
		1	1	1			1	1	1	
		1	1	1			1	1	1	

Desired image D

The image D above can be generated from F using a dilation or erosion operation followed by a second dilation or erosion. Assume H is a 3x3 matrix containing all ones. Ignore the border pixels. Below, specify the two operations (circle one), and for each one draw the entries of the image after that operation has been performed.

I = H applied to F

Circle one: dilation or erosion

D = H applied to I

Circle one: dilation or erosion

[Solution: Read Segmentation lecture slides]

NAME: ____

Problem 5: Recognition

You are working for a special effects company and want to have real actors inserted into a computer-generated world. One way to do this is to film the actors in front of a blue screen, so that the background can easily be segmented and substituted with a computer-generated one.

Due to lighting variations, the background will not appear pure blue, so checking for a single intensity value might not work well. Instead, you decide to model the distribution of background colors as a probability function. You are given a training image T with pixels labeled as foreground (F) and background (B).

Part A

Define each of the following probability functions based on T. In your functions, you can refer to properties of the image T like "number of pixels labeled as foreground in T".

Let P(B) denote the probability that a particular pixel is a background pixel, irregardless of its color or position in the image.

P(B) = ____

Let P(**c** | B) denote the probability that a background pixel has color **c**

P(**c** | B) = ____

Part B

What probability function would you need in order to perform the background classification on a new image? Specify this probability function in the form of P(X | Y), and specify its relation to the probabilities in Part A. You may use Bayes rule if need be.

[Solution: Read Pattern Recognition II lecture slides]

NAME: ____

Part C

Suppose the colors of the background pixels all occur roughly on a line in the 3D color space of RGB. Describe how to compute that line by forming a matrix **A** and computing eigenvalues and eigenvectors of that matrix. (hint: think about how you compute eigenfaces—it's the same idea except in color space)

Let $\mathbf{c}_1, \ldots, \mathbf{c}_m$ be the colors of the set of B pixels in T. Each color is a column vector with three components (RGB). Define the matrix **A**. Also define any other terms that you use in your definition of **A**:

A =

Suppose that $\mathbf{v}_1, \mathbf{v}_2, \ldots, \mathbf{v}_n$ are the eigenvectors of A, with corresponding eigenvalues $\lambda_1, \lambda_2, \ldots, \lambda_n$, sorted from largest to smallest.

What is the relationship of $\mathbf{v}_1$ to the line you're trying to compute?

How would you use $\mathbf{v}_1$ and the mean background color to compute whether the color **c** of a new pixel is background (give the formula)?

[Solution: Read Object Recognition lecture slides]