ECE/OPTI 532 Final Exam
Fall 2020

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Name

- This is a 2-hour exam.
- You will use your own paper to write your answers.
- You get an additional 30 minutes to scan or take a photo of your pages and submit it to D2L Assignments. Alternatively, some students use the CamScanner PDF Scanner App on their smartphone (3-day free trial and $49.99/year).
- After you complete the exam, scan or photograph your pages, and upload as PDF or images to D2L Assignments by 6:00 p.m.
- Late papers may not be accepted.
- Be sure to show your work. You must explain the detailed steps of your work, or else you may not receive credit even if the answer is correct.
- You may use a textbook, the lecture notes, your own notes, the posted homework problems and solutions, and a calculator.
- Otherwise, you may not consult any other resource (Google or other search engine, phone, text messaging, social media, email, etc.) that would not be allowed during a supervised, in-classroom exam.
- You may not share your exam questions, answers, scratch paper, or any information regarding content of the exam with other persons.
- The minimum sanction for academic dishonesty on an exam is a grade of E for the course.

I agree to obey these exam rules, as well as all university rules regarding academic integrity.

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Signature

Problem 1

Discuss non-maximum suppression in the context of edge detection. Provide as many details as possible. Discuss the various choices one must make when implementing this technique, including methods to obtain accurate results and user parameters that may be needed. Show diagrams and equations, but no code.

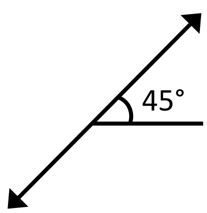
Problem 2

For the Prewitt operator, the response to diagonal edges is not the same as the response to horizontal and vertical edges. Which type of edge is favored and by how much? Show an example using an (infinitely long) ideal 2-D digital step edge with gray-level 0 on one side and gray-level 10 on the other side. Repeat the analysis using the Sobel operator.

Problem 3

For the following image, compute the symmetric co-occurrence matrix using angle 45° (as shown below) and a one-pixel distance (i.e., the sum of the occurrences at angle 45° and the co-occurrences at angle –45°.) Assume the values are zero outside the area shown. Assume the maximum possible gray level is 3.

2	2	1	1
3	1	3	1
0	3	0	0
0	3	1	2



Problem 4

Consider the problem of generating a bilevel image from a grayscale image. Kittler and Illingworth proposed a technique for thresholding bimodal histograms by minimizing the Kullback information distance. Otsu's thresholding technique is also popular. However, in the presence of noise, the histogram can be ragged with ambiguous valleys, so the selected threshold may be inaccurate. Also, the labeling of a noisy pixel may be inconsistent with the labels of neighboring pixels, leading to errors in the bilevel image. Assuming that we are restricted to histogram thresholding techniques, discuss several ideas for how we might improve upon the simple, Kittler or Otsu thresholding by incorporating information about intensity gradients, spatial relationships between pixels, etc. Discuss as many possible improvements as you can think of. Format your answer using a list or "bullet" format.

Problem 5

Apply the classical, <u>non-iterative</u> connected components labeling algorithm (using label equivalences) to the following image. Use 4-connectedness. (Alternatively, you may show the top-down bottom-up iterative algorithm for partial credit.) The final, labeled image must have consecutively numbered labels, starting with the background having label 0. Show the intermediate image arrays at each step of the algorithm, along with any auxiliary tables that are used in the algorithm, as well as the final, labeled image.

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●	●		●
	●	●	●
●			

Problem 6

In the analysis of bilevel images, we discussed two types of connectedness: 4-connected and 8-connected. Suppose we use the same type of connectedness for both the object pixels and the background pixels. Explain why this is a bad idea. Also, show an example where this incorrect choice of connectedness can change the genus of an image.

Problem 7

Let $x(r,c)$ be an $N \times N$ input image. Let $s(r,c)$ be the closest approximation to a circular-disk structuring element with radius R, with origin at the center of the disk. Let $y(r,c)$ be the $N \times N$ output image. Assume that approximately half of the pixels are object pixels, or 1-pixels. Write a pseudo-code description (or high-level language of your choice) of a computer algorithm to implement morphological binary **<u>erosion</u>** using pixel operations in a computationally efficient way. You may ignore array bounds checking and may assume that when an array index is out of bounds, the returned value will be 0 (background). Ignore variable declarations and input/output statements. For example, you may use statements such as

$s(r,c) = \text{makedisk}(R,N)$

for $r = 0$ to $N-1$

for $c = 0$ to $N-1$

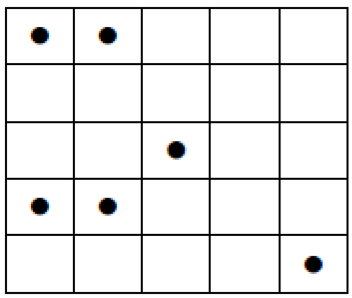
if $x(r,c) = \cdots$

then $y(r,c) = \cdots$

else ...

Problem 8

Use the Hough transform to detect straight lines in the following edge map. Use the $y = mx + b$ parameterization. Let the x-axis point to the right and the y-axis point up, with the origin at the lower left pixel. Limit the Hough space to $m \in \{-2, -1, 0, 1, 2\}$ and $b \in \{-1, 0, 1, 2, 3, 4\}$. Draw the Hough array and fill it in with the appropriate values. Explain your method for filling the Hough array. What is the equation of the strongest line? What threshold should be used to detect it?



Problem 9

Consider a binocular stereo computer vision system arranged in a non-convergent geometry (parallel optical axes). The two cameras each have a focal length of $f = 6$ cm, and are separated by a baseline distance of $b = 10$ cm. Each pixel corresponds to a discrete sensing element in a CCD array. The sensing elements are arranged on a rectangular grid, with a spacing of 0.1 mm between the sensor element centers. Recall that depth can be is reconstructed as bf/d. A feature in the scene is identified in each image and correctly matched. The feature coordinates in the left image are $(x_L, y_L) = (390, 0)$ pixels, and the coordinates of the same feature in the right image are $(x_R, y_R) = (340{,}0)$ pixels. The coordinates are normalized so that the center pixel in each image has coordinates (0,0).

(a) What is the depth, $-z$, of the feature from the camera baseline (in meters)?

(b) In practice, the actual position of a feature in the image can only be determined within 1/2 pixel in each direction. Assuming that there is no error in the vertical position of the feature, what is the range of values that the depth, $-z$, can have, given the above feature coordinates? I.e., determine the accuracy of your answer to part (a).

Problem 10

Explain the procedure for performing binary morphological opening. And then compute the binary morphological opening using the following image A and structuring element B. The location of the origin and orientation of the axes is as shown. Assume the arrays are extended by background. Show the output of the opening operation.