CSE166 – Image Processing – Final

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`http://www-cse.ucsd.edu/classes/fa11/cse166-a`

11:30am-2:30pm Thu. Dec. 8, 2011.

On this exam you are allowed to use a calculator and two 8.5" by 11" sheets of notes. The total number of points possible is 56. Good luck!

Part I: Fill in the Blank (1 pt. per blank, 20 pts. total).

1. True or False: k-means is an unsupervised learning method. _____
2. True or False: a minimum distance classifier is a supervised learning method. _____
3. If X is an $n \times k$ matrix with $k < n$, the rank of the matrix $XX^\top$ is _____ .
4. When computing the covariance for a set of vectors, we must first _____ the data.
5. PCA applied to face recognition is known as _____ .
6. True or False: Huffman Coding assigns infrequently occurring symbols short codewords. _____
7. A good choice of kernel for enhancing oriented fingerprint ridges while suppressing noise would be a(n) _____ .
8. The convolution of the 3rd row and the 5th row of Pascal's triangle yields _____ .
9. An affine transform is fully specified by _____ corresponding point pairs.
10. True or False: JPEG is recommended for compressing pages of scanned text. _____
11. True or False: Lucas-Kanade is a variable length coding algorithm. _____
12. The ambiguity of motion viewed through a small window is known as the _____ .
13. The axes of greatest and least variance for a shape are given by the _____ of the scatter matrix.
14. A neighborhood of an image containing a straight edge is an example of a rank-_____ neighborhood.
15. If you convolve a box with itself over and over, its shape will tend to a(n) _____ .
16. The _____ transform was originally invented for detecting extended lines in images.
17. The signal $f(x) = (-1)^x$ for integer x is known as the _____ component.
18. The columns (or rows) of the DFT matrix are _____ to one another.
19. The DFT of a box LPF exhibits an undesirable artifact known as _____ .
20. The DFT of an odd-symmetric function is purely _____ .

Part II: Written problems.

1. (5 pts.) Consider the system $g(x) = \sum_{k=x-2}^{x+2} w(k)f(k)$, where $w(\cdot)$ equals the 7th row of Pascal's triangle. Determine whether this system is LSI, and show your work. If it is LSI, what is the impulse response $h(x)$? If it is not LSI, provide an intuitive explanation of why it isn't.

2. (15 pts) Consider the 7×7 binary image shown in Figure 1 in which black=1 and white=0. Assume the top left coordinate is $(0, 0)$.

   (a) Sketch the Hough Transform for this image using the normal line (ρ, θ) parameterization. On your drawing, let ρ range from 0 to 10 and let θ range from $-\pi/2$ to $\pi/2$.

   (b) Indicate the points of intersection on your sketch and explain what they represent in the input image.

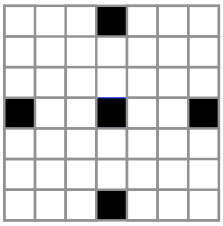

Figure 1: 7×7 binary image. The coordinates of the five nonzero pixels are: $(0, 3)$, $(3, 0)$, $(3, 3)$, $(6, 3)$, $(3, 6)$.

3. (3 pts) Suppose that before compressing an image (e.g., using Huffman coding) we filter it with the kernel $[-1 \quad 1]$.

   (a) What quantitative measure of image compressibility is affected by this filtering operation?

   (b) Explain how one might benefit from such a strategy in terms of characteristics of the pixels in the input image.

4. (7 pts) Let $f(x, y)$ denote an $M \times N$ grayscale image of an outdoor scene (e.g., house, tree, sky), and denote its raw histogram $h(k), k = 1, \ldots, K$.

   (a) What is $\sum_{k=1}^{K} h(k)$?

   (b) Sketch an example of $f(x, y)$ and its corresponding $h(k)$. Annotate the histogram in at least two places to show what the various parts represent w.r.t. the image.

   (c) Suppose you filter the image with an LoG kernel. Sketch the histogram of the resulting image, and explain why it looks the way it does. How does the entropy of the filtered image compare to that of the original image?

5. (6 pts) Recall the chi-squared distance between a pair of normalized histograms:

$$\chi^2(i, j) = \frac{1}{2} \sum_{k=1}^{K} \frac{[h_i(k) - h_j(k)]^2}{h_i(k) + h_j(k)}$$

   (a) What is the chi-squared distance between two identical histograms? Show that $\chi^2(i, j)$ cannot be smaller than this value.

   (b) What is the largest possible chi-squared distance between two histograms? Show that $\chi^2(i, j)$ cannot exceed this value.