**CSE166 – Image Processing – Final**

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`http://www-cse.ucsd.edu/classes/fa04/cse166`

11:00am-2:00pm Tue. Dec. 7, 2004.

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 43. Good luck!

Part I: Fill in the Blank (1 pt. each).

1. The DC component is the lowest frequency component of the DFT; the highest is the _____ component.
2. The $N$th row of _____ is produced by convolving the $(N-1)$st row with `[1 1]`.
3. The 8-point DFT of $f(x) = \cos(\pi x/2)$ has exactly _____ nonzero value(s).
4. The _____ transform of a square is a parallelogram.
5. When computing the Hough transform, each pixel in the $(x, y)$ domain produces a _____ in the $(\rho, \theta)$ domain.
6. A neighborhood of an image where half the gradient vectors point to the left and half point to the right is an example of a rank-_____ neighborhood.
7. We compute $I(x, y, t) - I(x, y, t-1)$ as an approximation of _____ .
8. The fact that image motion is ambiguous when viewed within a small window is known as the _____ problem.
9. _____ is an example of a variable length coding scheme.
10. True or False: JPEG is recommended for compressing scanned images of text. _____
11. An image with a highly peaked histogram has _____ entropy than an image with a flat histogram .
12. The inverse Fourier transform of a Gaussian is a(n) _____ .
13. Suppose $f(x)$ is a box function. The function $f(2x)$ is twice as _____ as $f(x)$.
14. If you forget to zero-pad when filtering in frequency domain, it can result in an problem in the resulting image known as _____ .
15. The zero-crossings of the _____ filter can be used to detect edges on the crack lattice.
16. When a 2D kernel can be expressed as the outer product of two 1D kernels, we say that the 2D kernel is _____ .
17. Given an RGB image, the _____ channel representation is given by the three images $R - G$, $B - (R + G)/2$ and $(R + G + B)/3$.
18. The image enhancement operation that makes the probability density function of pixel brightnesses approximately uniform is called _____ .
19. The axes of elongation of a shape are given by the eigenvectors of the _____ matrix.
20. The decision boundary of a minimum distance classifier between two classes in a 2D feature space is a(n) _____ .

Part II: Written problems.

1. (13 pts) This problem makes use of the binary image displayed in Figure 1, in which black=1 and white=0. Note: in calculating the various quantities in this problem, round your answers to 2 significant figures.

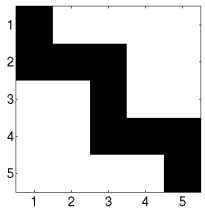


Figure 1: $5 \times 5$ binary image.

   (a) Compute the coordinates of the centroid $\mathbf{m}$.

   (b) Compute the scatter matrix $C$.

   (c) Find the eigenvalues $\lambda_1$ and $\lambda_2$ of $C$ and use them to compute the aspect ratio.

   (d) Find the angle $\phi$ of the principal eigenvector of $C$. Also write down the angle of the 2nd eigenvector. Express each answer in units of degrees.

   (e) Letting $\mathbf{x}_k$ denote the original coordinates of the nonzero pixels, find the values of the rotation matrix $R$ and translation vector $\mathbf{t}$ in the expression

$$\mathbf{x}'_k = R(\mathbf{x}_k + \mathbf{t}), \quad k = 1, 2, \ldots, 9$$

   such that the set of transformed coordinates $\mathbf{x}'_k$ for $k = 1, 2, \ldots, 9$ is centered at the origin and has its principal axis aligned with the $y$ axis.

2. (5 pts.) You are given an image $f(x, y)$ of size $128 \times 128$ and a kernel $h(x, y)$ of size $9 \times 9$. Explain the steps necessary to compute the convolution $g = f * h$ via frequency domain filtering, using zero padding to avoid aliasing. Your result should match what you would get by running the command `g=conv2(f,h)` in Matlab. Illustrate your answer with diagrams.

3. (5 pts.) Define $h(x)$ to be the 3-tap binomial kernel, centered at $x = 0$. Now define the function $H(u)$ as:

$$H(u) = \sum_{x=-\infty}^{\infty} h(x) e^{-j2\pi ux}$$

   In this problem, $x$ is discrete and $u$ is continuous.

   (a) What does $H(u)$ represent?

   (b) Plug in the values of $h(x)$ to solve for $H(u)$, and write it in its simplest form.

   (c) Sketch $H(u)$.

   (d) Based on the shape of $H(u)$, what type of filter is $h(x)$?