CSE166 – Image Processing – Final
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`http://www-cse.ucsd.edu/classes/fa07/cse166`
11:30am-2:30pm Wed. Dec. 12, 2007.

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 50. Good luck!

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

1. The Fourier transform of a narrow Gaussian is a(n) _____ _____ .

2. $\nabla I(x, y)$ is computed in Matlab using the function _____ .

3. A neighborhood of an image where all the gradient vectors are proportional to $(\pm 1, 1)^\top$ is an example of a rank-_____ neighborhood.

4. The convolution of an $N \times N$ kernel with itself is of size _____ .

5. The image enhancement operation that makes the probability density function of pixel brightnesses approximately uniform is called _____ .

6. _____ is an example of a lossless image compression method.

7. The lower bound in lossless image compression is set by the _____ of the source.

8. Convolution in the spatial domain corresponds to _____ in the frequency domain.

9. Laplacian of Gaussian and Gabor filters are _____ -pass filters.

10. The _____ of an image $I(x, y)$ is a vector field in which each vector points in the direction of greatest change from dark to light.

11. Given a function $f(x)$, the value of the DFT $F(u)$ at $u = 0$ is also known as the _____ -component.

12. A odd-symmetric Gabor filter is formed by computing the product of a(n) _____ and a(n) _____ .

13. _____ is a technique for dimensionality reduction based on the eigenvectors of the covariance matrix for a set of feature vectors.

14. The decision boundary of a minimum distance classifier between two classes in a 3D feature space is a(n) _____ .

15. Hough's original parameterization blew up in the case of _____ lines.

16. The Fourier transform of a box filter is a(n) _____ .

17. _____ is an iterative clustering algorithm that alternates between cluster assignment and centroid re-estimation.

18. The _____ probability is proportional to the prior probability times the class conditional density.

19. True or False: convolution with `[1 -1]` improves the compressibility of piecewise constant images. _____

Part II: Written problems.

1. (10 pts) Let `W=dftmtx(8)`.

   (a) Explain in words what each row of `W` represents.

   (b) Write down the result of the operation `(1/8)*W*W'`.

2. (3 pts.) Consider the system $g(x) = \sum_{k=x-2}^{x+2} f(k)$. 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.

3. (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.
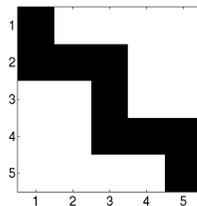

Figure 1: 5×5 binary image.

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

   (b) Compute the scatter matrix C.

   (c) Find the eigenvalues λ_1 and λ_2 of C and use them to compute the aspect ratio.

   (d) Find the angle ϕ 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.

4. (4 pts.) Prove that the eigenvalues of a covariance matrix are non-negative. What is this property called?