Practice Questions for CS 663

NOTE: The practice questions below cover topics after the mid-sem, but the final exam is comprehensive and includes all the stuff we covered during this course right from the first week.

1 Image Segmentation

1. Write a formula for a kernel density estimate of a scalar variable x using Gaussian kernels if you had access to the following 4 values of samples of x: 1,-1,2,4.

2. Write a formula for a kernel density estimate of a multivariate variable $\mathbf{x}$ using Gaussian kernels if you had access to the following 4 values of samples of x: (1,-1),(2,4),(4,2),(1,1).

3. What is the advantage of a kernel density estimate over a histogram? What are the disadvantages?

4. Suppose you want to execute K-means based image segmentation. Suppose you perform the clustering by using only the intensity values in one experiment, and by using the intensity values along with the pixel coordinates in another experiment. What is the qualitative difference in the outputs?

5. Derive the equation for a mean shift vector at a sample $\tilde{x}$ given N samples $\{x_i\}$, $1 \leq i \leq N$.

6. What is the difference between image smoothing using mean shift and image smoothing using bilateral filtering?

7. Write MATLAB code to sample from the following probability density function: $p(x) = 0.3e^{-x^2} + 0.7e^{-((x-2)/10)^2}$, assuming you have access to a routine called 'randn' which drawns a sample from a 1D Gaussian centered at 0 and having standard deviation 1, and another routine called 'rand' which draws a sample uniformly at random in the range [0,1].

8. Enlist any demerits of the mean shift method for image segmentation.

9. What are the problems with the K-means method for image segmentation.
10. What are the advantages of mean-shift over K-means?
11. Suppose I computed the local edge direction at every pixel in an image, and used it in a voting scheme only if its gradient magnitude is above some threshold. How does this procedure differ from a conventional Hough transform? What are the pros and cons?

2 Image Compression

1. The JPEG standard divides the image into 8 X 8 blocks, computes the DCT coefficients of each block, nullifies coefficients whose magnitude falls below a certain threshold and stores only the rest. Instead of DCT of each block, suppose I used the SVD of each block? (Read the notes on SVD). What will be the advantages (if any) and disadvantages (if any)?
2. What is the relationship between the DCT bases and the PCA basis computed from a large ensemble of small patches collected from images of several different types?
3. Draw the Huffman tree and the expected number of bits to store a random variable that takes on the four values (1,2,3,4) with probabilities 0.1, 0.2, 0.3, 0.4 respectively. For what values of these probabilities, will the expected number of bits be maximum? minimum?
4. Given a patch of size $n \times n$ represented as a matrix and given the orthonormal matrix U of size $n \times n$, explain how you will compute the 2D-DCT coefficients of the patch.
5. How is DCT computed using DFT?
6. JPEG is a lossy compression algorithm. At which portions of an image does it cause more errors as compared to others?
7. Suppose I pulled out an image from a comic strip - it has intensity values that are piecewise constant or piecewise linear. If you apply JPEG to such an image, what kind of artifacts will you see? Can you suggest a method that may avoid these artifacts?
8. What is the use of the YCbCr color space in color image compression?

3 Principal Components Analysis and SVD

1. What is the criterion that PCA seeks to minimize?

2. Why are the different eigencoefficients decorrelated?

3. In face recognition, the size of the images is much more than the number of images. What speed-up trick is used in such cases?

4. What is the relationship between the singular values of a matrix A and the eigenvalues of $A^T A$ and AA^T? Between the singular vectors of A and the eigenvectors of these matrices?

5. Consider the equation $Av = 0$ where A is a low rank matrix. Prove that v is obtained (up to a scaling factor) as the right singular vector of A corresponding to its zero singular value.

4 Image Restoration

1. Derive a formula for motion blur kernel when an object is moving at a fixed speed parallel to the imaging plane.

2. What are the problems with an inverse filter? How does the Wiener filter solve those problems?

3. What is the relationship between inverse filter in the Fourier domain, and an inverse filter using matrix inversion? Here by matrix, I refer to the circulant matrix for a given blur kernel.

4. In spatially varying PCA for denoising, how do you get an estimate of the SNR? What are the 'free parameters' in this method?