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ECE 178 **Sample Problems**

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Question 1

1. Synthetic Aperture Radar (SAR) images contain what is commonly referred to as the speckle noise. This noise is multiplicative, i.e., the observed signal at a pixel location (x, y) is $s(x, y) = f(x, y)n(x, y)$, where $f(x, y)$ is the true signal and $n(x, y)$ is the noise component. Further, let us assume that the true signal being observed is bandlimited to a circularly symmetric region of radius ***D*** centered at the origin in the frequency domain, and the noise is mostly high frequency. Suggest a suitable scheme to recover the true signal $f(x, y)$.

2. A certain imaging system can be modeled as $g(x, y) = \log(f(x, y) + n(x, y))$, where $f(x, y)$ is the signal of interest, $g(x, y)$ is the observed data and $n(x, y)$ is the noise. As is typical, the noise component is dominant in the high frequency spectrum and the signal of interest is mostly of low frequency components. Suggest a suitable method to enhance the quality of the observed signal while de-emphasizing noise. Explain your answer.

Question 2

1. A 100x100 pixel digital image has five distinct intensity levels. We would like to code this image in a loss-less way.
   a. What is the minimum number of bits required if no additional information is available?
   b. What is the minimum number of bits required if the intenisty levels are distributed as follows: the first number indicates the level and the second number indicates the number of pixels corresponding to that level. (1, 2000); (2, 4000); (3, 1000); (4, 1000); (5, 2000)
   c. For each of the above two cases, construct an optimal code assuming each pixel value is coded individually.

2. Consider an image whose pixel values range from 0 to 8. The level “0” has a 0.5 probability and the remaining levels are equi-probable. What is the entropy of this image in bits/pixel? Construct a Hauffman code for the gray levels assuming that each of the pixels values are coded separately. What is the average number of bits/pixel of the coded set of values

3. How many unique Huffman codes are there for a three-symbol source? Construct them.

4. Prove that, for a source with q symbols, the maximum value of the entropy is $\log q$, which is achieved if and only if all source symbols are equiprobable.

Question 3

1. Histogram equalize the following 8x8 image where the pixels take on values {0,1,..,7}. Clearly state any assumptions you make.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 2 & 2 & 2 & 3 & 4 \\ 1 & 1 & 1 & 2 & 2 & 2 & 3 & 4 \\ 1 & 1 & 1 & 2 & 2 & 2 & 3 & 4 \\ 1 & 1 & 1 & 2 & 2 & 2 & 3 & 5 \\ 2 & 2 & 2 & 2 & 2 & 5 & 5 & 5 \\ 6 & 6 & 6 & 6 & 7 & 7 & 5 & 5 \end{bmatrix}$$

2. Consider a digital image that has been histogram equalized. Discuss what happens when this image this image is equalized again.
3. Consider a video telephone application where a very low bit rate image coding is required. In designing such a coder, it is assumed that the primary changes that occur in the images will be in the eye and mouth regions. Suppose we have stored at both the transmitter and the receiver the overall face and many possible shapes of the left eye, the right eye, and the mouth of the video telephone user. At the transmitter, an image frame is analyzed, and the stored eye shape and mouth shape closest to those in the current frame are identified. The identification numbers are then transmitted. At the receiver, the stored images of the eyes and mouth are used to create the current frame. Suppose 100 different images are stored for each of the right eye, the left eye, and the mouth. Assume that each of these shapes is equally likely. What is the bit rate/sec of this system? Assume a frame rate of 30 frames/sec.

Question 4

1. Consider a 4 x 4 pixel sub-image . The variances of the 4x4-point DCT coefficients of are shown in the following figure. For a 2 bits/pixel DCT coder using zonal coding, suggest a good bit allocation map that can be used in quantizing the DCT coefficients.

16	4	2	1
64	16	4	2
256	64	16	4
1024	256	64	16

2. What is blocking artifact? Explain clearly why blocking artifact is less pronounced for DCT than DFT in image compression.
3. In image compression, typically the image is divided into smaller blocks of size 8x8 or 16x16 pixels and the transform of these sub-images is then taken. Why not take the transform of the whole image instead of partitioning the image into blocks? Explain your answer clearly. (*you can find more information in your text on the computational complexity;)*

Question 5

1. Explain how zonal coding is different from threshold coding.
2. Explain the role of the Quantization matrix in JPEG compression.
3. Explain clearly role of I-, P-, and B- frames in MPEG sequences. In particular, state how they are different from each other.
4. What is motion compensation? How does motion compensation help in video compression?

Question 6

State if the following statements are True or False.

a. Hauffman coding results in a lossy compression.

b. A more likely event has more self-information.

c. Transform coding is often used for loss-less image compression.

d. Transform coding reduces coding redundancy.

e. The DCT is the real part of the DFT.

f. Blocking artifact is less pronounced for the DCT than DFT in transform coding.

g. JPEG compression uses threshold coding.

h. JPEG compression standard uses DFT for compression.

i. Predictive coding reduces inter-pixel redundancies.

j. DCT closely approximates Karhunen-Loeve transform for a large class of images

EXTRA WORK (no solutions):

1. Sketch a schematic of the lossy predictive coding scheme and illustrate with an example how the feedback helps in controlling the error build-up due to quantization error. Your example should include an input sequence, a well-defined quantizer, reconstructed sequence with and without the feedback loop at the encoder and the intermediate steps in reconstruction.
2. You are given a face image database of the students in ECE178. Suggest a compression scheme which will enable you to store all these images in an optimal way (minimum mean squared error in reconstruction) for a given number of bits/pixel. Explain clearly with a block diagram.
3. State and explain a problem with the face recognition techniques using Eigenfaces.
4. Is it more logical to apply Huffman coding before Predictive coding or predictive coding before Huffman coding? Clearly state your reasoning.
5. Consider a three-symbol source {a,b,c} with probabilities P(a)=0.4, P(b)=0.5, and P(c)=0.1. Construct an arithmetic code for the string “bbbc”.