CS 3570 Introduction to Multimedia Technology
Midterm Examination (5/5/2023)
(Totally 7 questions and 115 points on 2 pages)

1. (12 pts) (a) Describe the step-by-step procedure of applying medium-cut method to convert a 24-bit RGB color image to 6-bit color image. (b) How do you measure the bit-rate saving and color quantization error in this case. (c) Briefly describe how you can apply error diffusion to reduce the color quantization artifact.

2. (16 pts) Consider the problem of image scaling of an M-by-N image to 3M-by-3N image. Assume the following image is the target image (scaled image). The inverse coordinate mapping from the target image to the original image is given by M(x,y) = (x/3, y/3). The pixel grayscale values at (30, 60), (30, 63), (33, 60), (33, 63) in the scaled image are given in the following table. Apply (a) nearest-neighbor interpolation and (b) bilinear interpolation to compute the interpolated values at A, B, C, D.

x / **y**	30	31	32	33	34
60	90			180	
61	A(?)	C(?)			
62	B(?)		D(?)		
63	270			90	
64					

3. (20 pts) Consider the 8-by-8 grayscale image given below, where the numbers (0, 20, 40, 80, 99) denote the gray-level intensities with 8-bit representation.
   (a) What is the entropy η of the image? Show your computation.
   (b) Show step by step how to construct the Huffman tree to encode the above five intensity values in this image. Show the resulting code for each intensity value.
   (c) What is the average number of bits needed for each pixel, using your Huffman code? How does it compare to the entropy η?
   (d) For this problem setting, what is the corresponding interval to encode the sequence of 3 grayscale values “0 80 40” by using arithmetic coding? How many bits are required to encode this 3-pixel sequence?

0	0	0	0	0	0	0	0
0	0	99	99	99	99	0	0
0	80	40	40	40	40	80	0
0	80	40	40	40	40	80	0
0	80	40	40	40	40	80	0
0	80	40	40	40	40	80	0
0	0	20	20	20	20	0	0
0	0	0	0	0	0	0	0

4. (16 pts) The 2D DCT formula for an M-by-N image *f*(r,s) is given below:

$$F(u,v) = \sum_{r=0}^{M-1}\sum_{s=0}^{N-1} \frac{2C(u)C(v)}{\sqrt{MN}} f(r,s)\cos(\frac{(2r+1)u\pi}{2M})\cos(\frac{(2s+1)u\pi}{2N})$$

   (a) Consider M=N=8, what is the basis function corresponding to the coefficient F(u,v)?
   (b) Consider applying DCT to the 8X8 image in Problem 3. What is the DCT coefficient F(0,0)?
   (c) Consider the encoding of an 8-by8 block with DCT in JPEG compression. Describe the step-by-step procedure of encoding the DCT coefficients (excluding the DC coefficient) into a bit stream.
   (d) Which of the step in your answer to (c) causes the main source of errors in the image compression? Explain why?

5. (20 pts) The DFT for a signal f =[f(0), …, f(N-1)] is given as follows:

$$F(n) = \frac{1}{N}\sum_{k=0}^{N-1} f(k)\, e^{-\frac{2\pi mk}{N}}$$

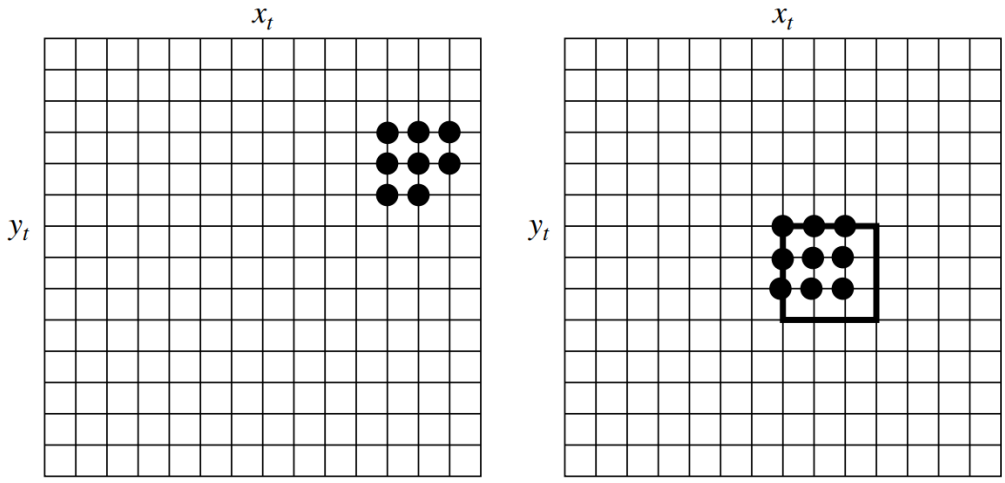
   (a) What are the magnitude and phase for the DFT coefficient F(n)? What is the physical meaning for the magnitude of F(n)?
   (b) What is the convolution between the above signal f and a filter h = [h(0), …, h(M-1)]? Give its mathematical definition.
   (c) How do you achieve the above convolution $f \otimes h$ through computation in the frequency domain? Give the specific steps of the computation.
   (d) Consider a signal f(k), k=0, .., 10000, in temporal domain, how do you apply a FIR filter to generate an echo effect for the input signal? Assume the sampling rate is 10K Hz and the echo is delayed by 0.2 seconds with amplitude reduced by 50%. Give the FIR filter h to generate this echo effect.
   (e) An IIR filter can be used to generate the echoing effect with infinite repeating echos. Give the corresponding recursive equation for the input sequence f(k) and the output sequence g(k), k >= 0, for this IIR filter.

6. (15 pts) Consider the example of motion estimation for inter-frame prediction in video compression in the following figure. The target (current) frame is a P-frame. The size of macroblocks is 4 × 4. The motion vector is MV(△x, △y), in which △x ∈ [−p, p], △y ∈ [−p, p]. In this problem, assume p ≡ 5. The macroblock in question (darkened) in the frame has its upper left corner at (x_t, y_t). It contains 9 dark pixels, each with intensity value 10; the other 7 pixels are part of the background, which has a uniform intensity value of 100. The reference (previous) frame has 8 dark pixels.

   (a) What is the best △x, △y, and sum of absolute differences (SAD) for this macroblock?

   (b) Show step by step how the 2D Logarithmic Search is performed, include the locations and passes of the search and all intermediate △x, △y, and SADs.

   (c) Compute how many 4X4 SAD calculations are needed for the full search and 2D Logarithmic search, respectively.



7. (16pt) (a) In video compression, what is intra prediction? Give an example. (b) What is an I frame, P frame or B frame? (c) What's the advantage of using an B frame? (d) What is the disparity in stereo vision? How is it related to the 3D depth perception?