CS 3570 Introduction to Multimedia Technology
Midterm Examination (5/4/2015)
(Totally 8 questions and 112 points on 2 pages)

1. (12 pts) (a) What are the two main steps to convert analog signal to digital signal? (b) What are the main factors that control errors in these two steps in the A/D conversion? (c) How do you adjust appropriate settings in these two steps to minimize the errors in A/D conversion?

2. (8 pts) Bitmap and vector graphics are two different types of image representation. (a) Give one-sentence definition for each of these two types of image representation. (b) What are the advantages and disadvantages for each of both types?

3. (8 pts) To scale a grayscale image I(x,y) of size 100X100 with 4 times horizontally and vertically, i.e. to size 400X400, by using the ***bilinear interpolation***. Give a simple pseudo code to perform this image scaling process.

4. (16 pts) Given an ordered sequence of (3n+1) 2D data points $\{(x_i, y_i) \mid i=1, .., 3n+1\}$ along an open curve, we would like to represent this curve with cubic Bézier curves in a piecewise manner. (a) Give the cubic Bézier curve representation. (b) Describe the procedure of determining the cubic Bézier curves for the whole open curve from the given data points. (c) How many cubic Bézier curves should be used to represent this curve by using all the data points? Why? (d) Does this cubic Bézier curve representation pass through all the data points? If not, how many data points does the Bézier curve pass through? Give reasons for your answer.

5. (20 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) What are the meanings for the variables u and v?
   (b) What does the value F(u,v) represent? Give your explanation as specific as possible.
   (c) For JPEG, describe why and how the 4:2:0 chrominance subsampling is used with the DCT for each 16-by-16 image block. How many 8-by-8 DCTs are required for each 16-by-16 block? Explain your answer.
   (d) How are the AC components of the DCT coefficients processed in JPEG compression?
   (e) How is the JPEG image compression ratio/quality adjusted?

6. (20 pt) (a) In the following 8-by-8 image, the numbers in the array denote the image intensity. Plot its image histogram.

(b) The numbers (0, 20, 50, 99) denote the gray-level intensities with 8-bit representation. What is the entropy of this 8-by-8 image?

(c) Show how to construct the Huffman tree to encode the above four intensity values in this image and the resulting code for all these four intensity values.

(d) What is the average number of bits needed for each pixel, using your Huffman code? How does it compare to the entropy computed in (a)?

(e) Use the run-length coding to represent the above image. Show the result. Discuss the optimal compression ratio that can be achieved with the run-length coding in this example.

99	99	99	99	99	99	99	99
20	20	20	20	20	20	20	20
0	0	0	0	0	0	0	0
0	0	50	50	50	50	0	0
0	0	50	50	50	50	0	0
0	0	50	50	50	50	0	0
0	0	50	50	50	50	0	0
0	0	0	0	0	0	0	0

7. (12 pts) The DFT for a signal f =[f(0), …, f(N-1)] is given as follows:

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

(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.

8. (16 pts) (a) Give a brief one-sentence definition for each of the following two filters: low-pass and band-pass, filters. (b) Also plot the corresponding transfer function, or the frequency response graph, for each type of these filters. In the graph, the x-axis is the frequency, and the y-axis is the fraction of frequency component retained in filtered signal. (c) Given a discrete audio 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. (d) 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.