CS 3570 Introduction to Multimedia Technology
Midterm Examination (4/28/2017) (Totally 8 questions and 112 points on 2 pages)

1. (12 pts) (a) What are the two main steps to convert analog signal *f*(t) to digital signal? Give the specific representation of the converted digital signal with its relationship to the original signal *f*(t). (b) What is the Nyquist rate? What is its relationship to the A/D conversion? (c) What is the dynamic range? What is its relationship to the A/D conversion?

2. (16 pts) Consider compressing a 20X20 color image, which is composed of 5 colors, represented by A, B, C, D, and E. The color histogram for the image is given as follows.

color	A	B	C	D	E
frequency	50	100	25	25	200

(a) Calculate the probabilities associated with the five colors in this case. (b) Based on the Shannon's theory, what is the average bits per pixel required for the color information based on the associated entropy computation? Show the details of your calculation. (c) Show how to construct the Shannon-Fano coding tree to encode the five colors in this image and the resulting binary code for each color. (d) Show how to use the **arithmetic** coding to encode a sequence of three colors: B-E-A.

3. (12 pts) To scale a grayscale image I(x,y) of size 100X100 with 3 times horizontally and vertically, i.e. to size 300X300, by using **(a)** ***nearest-neighbor interpolation*** **and (b)** ***bilinear interpolation***. Give a simple pseudo code for each of these two image scaling procedures.

4. (12 pts) Given a color image I(x,y) = (R(x,y), G(x,y), B(x,y)) in RGB color space, assume this image is too dark in overall appearance. (a) Describe how to brighten this color image with a **Gamma** transformation without changing the Chrominance components. (b) Discuss the selection of the Gamma parameter and plot the Gamma transformation curve for this problem. (c) Give the procedure for applying a median filter to reduce noises in the image I.

5. (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) What does the value F(u,v) represent? Give your explanation as specific as possible.
   (b) For JPEG, describe why and how the 4:2:2 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.

(c) Give the steps of processing the AC components of the DCT transform in JPEG compression?

(d) Describe in details how the image compression ratio/quality is adjusted in JPEG?

6. (12 pts) The DFT for a discrete 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.

7. (12 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) 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. Assume the sampling rate is 10K Hz and the echo is delayed by 1 second with amplitude reduced by 50%.

8. (20 pts) Consider video compression in the MPEG standard. Assume a video is compressed with the GOP sequence: IBBPBBPBBI. (a) What are the I, B, P frames in the above GOP sequence? (b) Give the encoding and decoding order for a GOP sequence. (c) Why is motion estimation needed for MPEG video compression? (d) When the size of a macroblock is 8X8, write down the pseudo code for finding the block motion vector for a target image block T(x,y), $0 \le x, y \le 7$, (P frame) from the reference frame R(i,j) with the search range within [-15, 15] along x and y directions. Use the SAD for the block matching criterion here. (e) Plot the flow chart for compressing a macroblock in a P frame with motion estimation, entropy coding, DCT, and quantization.