CS 3570 Introduction to Multimedia Technology
Midterm Examination (5/9/2016)
(Totally 8 questions and 115 points on 2 pages)

1. (10 pts) (a) What are the advantages of digital signal representation over analog representation? (b) How do you reduce errors in the A/D conversion process? Be as specific as possible.

2. (15 pts) Given a 16-by-16 image formed by 6 colors (Black, White, Red, Green, Blue, Yellow), its color histogram is given as follows:

Color	Black	White	Red	Green	Blue	Yellow
# of pixels	128	16	8	64	32	8

   (a) Compute the corresponding probability distribution function (pdf) for the colors in this image.

   (b) Calculate the associated entropy for the pdf in (a), and explain what this entropy value means in this context.

   (c) Apply Shannon-Fano algorithm to obtain the entropy coding for these six colors. Compute the average bits per color symbol in this image by using the above entropy coding scheme.

3. (10 pts) For the color interpolation problem, the Bayer pattern is commonly used in color image acquisition. Assume we acquire the following RGB values in a small patch of an image. Calculate the RGB values for the three bold-face and underlined pixels (pixel 1, 2, and 3) by using the nearest-neighbor algorithm.

G=100	R=80	G=104	R=90	G=124
B=230	G=128	**B=224 (pixel 2)**	G=140	B=222
G=110	R=86	G=132	**R=88 (pixel 3)**	G=142
B=232	**G=125 (pixel 1)**	B=226	G=138	B=220
G=130	R=90	G=136	R=82	G=140

4. (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 basis images in the DCT transformation? Assume M=N=8, how many basis images are there?

   (b) What does the value F(u,v) represent? Give your explanation as specific as possible.

   (c) For JPEG, give a simple flow diagram for processing each 16-by-16 block? What is the main source of errors/distortion in the JPEG compression?

   (d) How are the DCT coefficients processed in JPEG compression? How is the JPEG image compression ratio/quality adjusted?

5. (15pt) 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 perform the above convolution $f \otimes h$ in the frequency domain? Give the specific steps.

6. (15 pts) Given a discrete audio signal f(i), i=0, …, 50000, we would like to filter the audio signal with an N-th order FIR (Finite Impulse Response) filter h(n), n=0, …, N-1. Assume the sampling rate is 5000 Hz.
(a) Describe how to filter the audio signal with the FIR filter [h(0), h(1), …, h(N-1)] in temporal domain. Give the mathematical equation for the filtering operation. Discuss the computational cost required in the above filtering operation.
(b) Plot the transfer functions for an ideal low-pass filter and an ideal band-pass filter
(c) What is an IIR (Infinite Impulse Response) filter? Give an IIR filter that can produce echo effect (mixing 0.1-second delayed signal with a decaying factor 0.5) for the above input signal f(i).

7. (15 pts) A Bézier curve is a parametric curve described by polynomials based on a sequence of control points. Consider a cubic Bézier curve determined by four ordered control points (p_0, p_1, p_2, p_3).
(a) Give the equation for representing the associated cubic Bézier curve P(t) with these control points and the associated blending functions.
(b) What are the four conditions imposed by the four control points onto the associated cubic Bézier curve?
(c) Try to justify the Bézier curve P(t) satisfies the four conditions given in (b).

8. (15 pts) Consider the task of motion estimation for a macroblock of size 8-by-8 in a video frame I_t (a P-frame of resolution 128-by-128) and the associated reference frame is R. Assume the search range is within +/-8 pixels.
(a) Assume SAD (Sum of Absolute Differences) is used as a measure for motion estimation. Give the definition for SAD here.
(b) Give a step-by-step pseudo code for full-search motion estimation for a macroblock in I_t.
(c) Give a simple flow diagram of MPEG compressing the P frame by using motion estimation and JPEG compression.