

Homework 1

CS414, Multimedia Systems (Instructor: Klara Nahrstedt)

Posted: February 22, 2008

Due: February 29, 2008 at 11:59pm CST

Important Instructions

This homework assignment should be done individually. Penalties for cheating as described in the grading policy on the course website apply. Solutions should be done with a document preparation system, such as LaTeX or Microsoft Word (figures may be drawn by hand). In the homework solutions, you should show all of your work that you used to arrive at each answer to the problems. If possible, a hard copy of the assignment should be turned into the instructor at the beginning of class on Friday. Otherwise, a hard copy of the assignment should be slid under the door to the instructor's office (3104 SC) by the specified deadline.

1. Problem (4 Points)

Consider two types of data streams with the following characteristics:

- Stream 1: strongly periodic, weakly regular, discrete data stream;
- Stream 2: weakly periodic, strongly regular, discrete data stream;

Describe in detail a multimedia application, which uses both of these types of data streams.

2. Problem (4 Points)

- a. (2 Points) Explain Pulse Code Modulation (PCM). Specifically, what is PCM? How is PCM used on audio data?
- b. (2 Points) Why is CD quality audio sampled at a 44.1 KHz frequency when the human hearing frequency range is only between 20Hz and 20 KHz?

3. Problem (12 Points)

Consider the HDTV-progressive format used in the United States for video transmission between a television station and a receiver device. (*Note: This progressive format is 24 bits/pixel, 60 Hz frame rate, 1080 scan lines, 960 visible lines, and a 16:9 aspect ratio.*)

- a. (5 Points) Compute the bandwidth requirements for this format when only visible lines are transmitted.
- b. (5 Points) Compare the bandwidth requirement for the above format with the bandwidth requirement for an NTSC-interleaved TV format with 24 bits/pixel, 30 Hz frame rate, 525 scan lines, 486 visible lines, and a 4:3 aspect ratio. Assume that both streams are required to transmit all scanned lines.
- c. (2 points) Consider the time code format *HH:MM:SS:FF* defined for video by the Society of Motion Picture and Television Engineers (SMPTE) where *HH* denotes hours, *MM* denotes minutes, *SS* denotes seconds, and *FF* denotes frame number. Given the SMPTE timestamp 00:01:00:10, convert it back to the original frame number using the NTSC frame rate of 30 frames per second.

4. Problem (10 Points)

Consider the following sequence of eighteen 8-bit audio samples: 245, 235, 236, 243, 257, 236, 243, 242, 245, 135, 236, 243, 257, 236, 243, 257, 236, 243. Notice that this sequence of eighteen samples takes $18 \times 8 = 144$ bits. Apply Differential Pulse Code Modulation (DPCM) to the sequence of samples. Also, do the following: (1) specify the coding table used, (2) specify the resulting DPCM-encoded sequence, and (3) compute how much compression can be achieved with DPCM.

5. Problem (40 Points)

Consider the following image with an 8x8 pixels block.

8	10	0	20	0	12	15	30
20	25	10	35	10	30	50	25
18	23	15	201	205	25	32	40
26	18	185	19	30	195	100	50
21	201	190	8	12	175	248	43
18	170	185	30	38	168	230	25
12	25	200	240	205	200	32	18
1	5	243	8	15	232	12	5

Perform the following operations on this block:

- a. (20 Points) Compute the DCT coefficients (use the DCT formulas in the notes).
- b. (10 Points) Quantize the transformed matrix (use the luminance quantization table in the notes for JPEG quantization).
- c. (10 Points) Perform a zig-zag scan compressing the resulting sequence with run-length encoding.

6. Problem (20 Points)

Consider the following alphabet $\{a,c,d,e,i,l,m,s,t,u,-\}$ with the following probabilities:

$$P(a) = 0.5, P(c)=0.1, P(d)=0.01, P(e)=0.05, P(i)=0.02, P(l) = 0.03, P(m)=0.16, \\ P(s)=0.04, P(t)=0.08, P(u)=0.008, P(-)=0.002$$

- a. (10 Points) Construct a Huffman tree and encode the word 'mat'.
- b. (10 Points) Encode the word 'mat' with arithmetic encoding. Which coding is more efficient for this particular example, Huffman or Arithmetic? Why is one coding more efficient than the other? (*Note: you should show the conversion of the resulting value from arithmetic coding to its corresponding binary fraction representation to compare the efficiency*).

7. Problem (10 Points)

Consider a video-on-demand (VoD) system consisting of clients requesting video streams with the following characteristics: 640x480 pixels, 16 bits/pixel, and 25 fps. This VoD system runs on top of a transport layer protocol (similar to UDP) that uses 9-KByte packets. This system also uses admission control and runs a negotiation protocol. Provide the following information assuming that the available bandwidth at the VoD server at request time in the UDP-like transport level is 5 Mbps:

- a. (5 Points) Specify the translation relation between the VoD application (in terms of video stream characteristics) and the UDP-like transport layer described above. Give the admission condition(s) at the transport layer at the VoD server. Also, determine how many clients the VoD server can support.
- b. (5 Points) Specify the negotiation protocol between the VoD client and VoD service to setup this connection.