Sample Midterm Questions –

Question
The high-frequency limit of human hearing extends to approximately 20 KHz, but studies have shown that intelligible speech requires frequencies only up to 4 K Hz.

- Justify why the sampling rate for an audio Compact Disc (CD) is 44.1 kHz. What is the Nyquist rate for reliable speech communications?
- Why do you think people sound different on the phone from in person?
- Suppose intelligible speech requires 7 bits per sample. If the phone system is designed to just meet the requirements for speech (which is the case), what is the maximum bit rate allowable over telephone lines?
- CDs use 16 bits per sample. What is the bit rate of music coming off a CD? Is a modem connection fast enough to support streamed CD quality audio?

The ear is the ultimate receptor of the rendered digital audio. Since it can hear frequencies no more than 20KHz, the original signal must be sampled at at least 40 KHz to capture all the 20KHz frequencies. With some additional room for higher ranges, the CD audio is sampled at 44.1 KHz
Though the human larynx can produce frequencies only upto 4 KHz, different people have different frequencies for the same set of sounds depending on structure of mouth, tongue movement, etc. – same reason why a 256 Hz frequency sounds different on a guitar than on a piano.
Max bit rate over telephone lines = 2x4x7 = 56Kbps.
Bit rate of CD sound = 44.1x16 = 705.6 Kbps for mono, or 1.411 Mbps for stereo.
Broad band to most homes is getting to a point where this can be supported, but still for practical efficiency, the CD audio streams are compressed using a psychoacoustic audio compression scheme such as mp3 or AAC.

Question
Consider a discrete time source emitting equiprobable symbols A, B, C.

- What is the entropy of the source (assume $\log_2 3 = 1.585$)
- Encoding the source output symbol by symbol, find the average bit length per symbol. Give the example of a code achieving this.
- Encoding the source output in blocks of two symbols, how many bits/symbol are required on an average. Give an example code achieving this.

*H = 3 * 1/3*log3 = 1.585*
*Draw a Huffman tree and get a Huffman code. Find avg bit length sum(li*pi) = 1.667*
*Use symbols AA, AB, AC, BB, … (9 symbols in all), find their probabilities and get a Huffman code. Calculate bits per symbol as sum(li*pi)*

Question
Both subband coding and Subsampling seem to reduce sample sizes and attain compression.

- What is the main difference between them?
- What would motivate an encoding design to use subband as against subsampling?
- Explain how subband coding is used in MPEG1 audio
- Name the three modes of transmission in JPEG and classify them as closely as you can as being "subband coding" or "subsampling".

Subband coding gives different resolutions to different bands. Subsampling groups pixels together into a meta-region and encodes a single value for the entire region.
Subband if each different section band needs to be encoded differently
Audio PCM -> filter bank which gives different channel or bands -> each band separately encoded and quantized using different uniform quantization intervals. The quantization used for each band depends on the psychoacoustic model simulation output.
In JPEG – spectral selection (subband), successive approx. (neither, but closer to subband), hierarchical (subsampling)

Question

- What is the color gamut of a CRT screen?
- Why do most standards use the YCrCb color space instead of the RGB color space?
- Choose the color mode for each of the following types of projects: (Your choices are 1-bit, 8-bit grayscale, RGB, and CMYK.)
  a. You want to post a copy of your own artwork on your Web page.
  b. You need to put a copy of your signature on your computer-typed report
  c. You need to print the digital photograph of a pencil sketch of the map.

The color gamut of a CRT screen is the set of all reproducible colors.
YCrCb is preferable to RGB for image compression because it allows us to reduce the data size without compromising the image quality by 1) subsampling the chrominance channels and 2) quantizing the chrominance more corsely. Also, the Y, Cr and Cb channels are more uncorrelated and have smaller entropy than the R, G and B channels.

a) RGB b) 1-bit c) CMYK

Question

Suppose a camera has 450 lines per frame, 520 pixels per line, and 25 Hz frame rate. The color-subsampling scheme is 4:2:0, and the pixel aspect ratio is 16:9. The camera uses interlaced scanning, and each sample of Y, Cr, Cb is quantized with 8 bits.

- What is the bit-rate produced by the camera?
- Suppose we want to store the video signal on a hard disk, and, in order to save space, re-quantize each chrominance (Cr, Cb) signals with only 6 bits per sample. What is the minimum size of the hard disk required to store 10 minutes of video?

Repeat the exercise (both questions) assuming color subsampling scheme 4:2:2.

avg bits per pixel = (4x8+1x8+1x8)/4 = 12 bits
*Bit rate = num pixels/frame * numframes/second * avg bits per pixel.*
= (450x520)x25x12
= 70.2 Mbps
The only thing that changes because of the re-quantization is the average bits per pixel.
Assuming that Y, Cr, Cb all always have the same number of pixels –
Avg bits/sample = (4x6+1x6+1x6)/4 = 9
Bit rate = (450x520)x25x9
= 52.65 Mbps
*Disk size = 52.65*60*10 = 3.95 GBytes*

Question

- We have studied about constant bit rates (CBR) and variable bit rates (VBR) in class.
- Differentiate between CBR and VBR.
- Which one is normally preferable and why? Give your answer with regards to throughput and quality.
- Classify the following as producing VBR or CBR?
    - Huffman coding
    - Lossless Mode of JPEG Compression
    - MPEG1 Video
- A VBR video stream generates 420x320 pixels per frame at 20 frames per second, 8 bits per pixel. Consider a buffering strategy at the receiver with a 10 frame buffer to hold the frames so that they can be displayed at CBR. What is the minimum throughput (in Mbps) required from the network to display a video stream of 4 seconds.

CBR constant bit rate is preferred over VBR because throughput is greater, quality may be compromised depending on your bandwidth.
Huffman – VBR, Lossless Mode of JPEG – VBR, MPEG1 – VBR & CBR
70/4 x 420 x 320 x 8 = 18.816 Mbs

Question

In Video Encoding more compression is achieved by using block-based motion estimation and compensation. Let's called this temporal compression.

- Define I, P and B frames used in MPEG.
- Qualitatively explain how much of compression is achieved for each type of frame.

For first question, refer to text or lectures.
Compression of I < compression of P < compression of B