CMPT 365 Final Examination
Spring 2019

(Please answer all questions for a total of 100 points)

1. (15 points) [Short Answer Questions]

   (a) (1 point) In your opinion, what is the topic that we should have spent **more** time to discuss this semester?

   (b) (4 points) In HDTV, what does 1080p stand for? Why is it better than 1080i?

   Vertical res : 1080, progressive (non-interlaced). 1080i (interlaced) could cause blurring of obj moving.

   (c) (4 points) Name at least four factors that will affect the quality of a JPEG image.

   Lossless or Lossy, image resolution, Chroma subsampling, quantization, entropy coding (Huffman or Arith. coding)

   (d) (6 points) Briefly describe at least three examples in multimedia data compression in which **differential coding** is used.

   JPEG (DPCM on DC), Lossless JPEG, MPEG (Motion vectors), P/B frames, H264 Intra coding, ...

2. (15 points) [Entropy Coding]

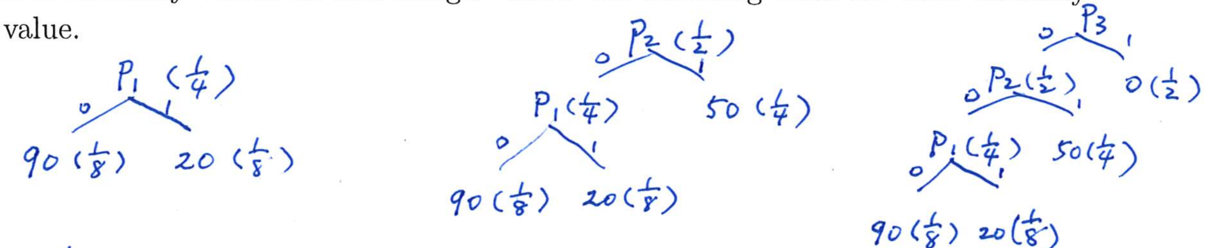
   5 (a) What is the *entropy* of the image below where numbers (0, 20, 50, 90) denote the gray-level intensities?
   [Hint: entropy $\eta = \sum_{i=1}^{n}(p_i \log_2 \frac{1}{p_i})$.]

   $P_{90} = 1/8$
   $P_{20} = 1/8$
   $P_0 = 1/2$
   $P_{50} = 1/4$

   $\eta = \frac{1}{8}\cdot\log_2 8 + \frac{1}{8}\cdot\log_2 8 + \frac{1}{2}\cdot\log_2 2 + \frac{1}{4}\cdot\log_2 4 = 1.75$

90	90	90	90	90	90	90	90
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

   10 (b) Show step-by-step how to construct the Huffman tree in order to encode the above four intensity values in this image. Show the resulting code for each intensity value.



Code: 90 → 000 20 → 001
50 → 01 0 → 1

Define a filter[t] = (0.1, 0.25, 0.3, 0.25, 0.1)

For vertical boundary pixels: new value $a_{i,j} = \sum_{t=-2}^{2} A_{i,j+t} \cdot \text{filter}[t]$

" horizontal " : " $a_{i,j} = \sum_{t=-2}^{2} A_{i+t,j} \cdot \text{filter}[t]$

** either do it on one side or both sides of the boundary.

3. (15 points) [Deblocking in H.264]

H.264 uses *In-loop Deblocking Filtering.*

3 (a) Why is it necessary? To eliminate the blocky effect (incontinuity at block boundaries)

6 (b) It is said many signal-adaptive deblocking filters can be used. Propose a simple deblocking filter of your own and explain how it works.

6 (c) How will you protect the real edges while doing the In-loop Deblocking Filtering?
Similar to slides 29-30, chap 12.

4. (15 points) [Digital Audio]

(a) (8 points) DVD Audio allocates up to 24 bits for each sample. It is aimed to provide better audio quality than Compact Discs (CDs) which uses 16 bits per sample.

$SQNR \approx 6N$ dB, where N is #_of_bits, so up to $6 \times 24 = 144$ dB

4 (i) What is the Signal to Quantization Noise Ratio (SQNR) for DVD Audio?

4 (ii) Explain why DVD Audio will sound better. (Don't just say because it has higher SQNR, explain what makes it sound better.) Given the same signal magnitude, the quantization noise (error) is reduced.

(b) (7 points) A low-pass filter is said to attenuate audio signals by 12 dB per octave after the cutoff frequency f. If the input voltage is maintained at the same level for all frequencies, and the output voltage at the frequency f is V_0, what is the output voltage (measured in percentage or fraction of V_0) at $4f$?
[Hint: $\log_{10} 2 \approx 0.3$].

$4f$ is two octaves higher than f, so the signal is reduced by 24 dB at $4f$.

$$20 \log_{10} \frac{V_0}{V_{new}} = 24 \text{ dB}$$, where V_{new} is the output at $4f$.

$$\frac{V_0}{V_{new}} = 2^4$$

$\rightarrow$ the output voltage at $4f$ is $\frac{V_0}{16}$.

6. (20 points) [H.264]

P-frame coding in H.264 uses *integer transform*:

$$F(u,v) = H \cdot f(i,j) \cdot H^T, \text{ where } H = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix}.$$

4 (a) What are the two advantages of using integer transform? (1) Faster (2) No drift (accum. of errors)

(b) Assuming the Target Frame below is a P-frame. For simplicity, assume the size of macroblock is 4 × 4. For the macroblock shown in the Target Frame:

2 (i) What should be the Motion Vector? (3, 3)

2 (ii) What are the values of $f(i,j)$ in this case?

12 (iii) Show all values of $F(u,v)$.

j

i

20	40	60	80	100	120	140	155
30	50	70	90	110	130	150	165
40	60	80	100	120	140	160	175
50	70	90	110	130	150	170	185
60	80	100	120	140	160	180	195
70	90	110	130	150	170	190	205
80	100	120	140	160	180	200	215
85	105	125	145	165	185	205	220

Reference Frame

110	132	154	176	–	–	–	–
120	142	164	186	–	–	–	–
130	152	174	196	–	–	–	–
140	162	184	206	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–

Target Frame

$$f(i,j) = \begin{bmatrix} 0 & 2 & 4 & 6 \\ 0 & 2 & 4 & 6 \\ 0 & 2 & 4 & 6 \\ 0 & 2 & 4 & 6 \end{bmatrix}$$

$$H \cdot f(i,j) = \begin{bmatrix} 0 & 8 & 16 & 24 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$H^T = \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix}$$

$$F(u,v) = \begin{bmatrix} 48 & -56 & 0 & -8 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

6. (20 points) [SNR Scalability]

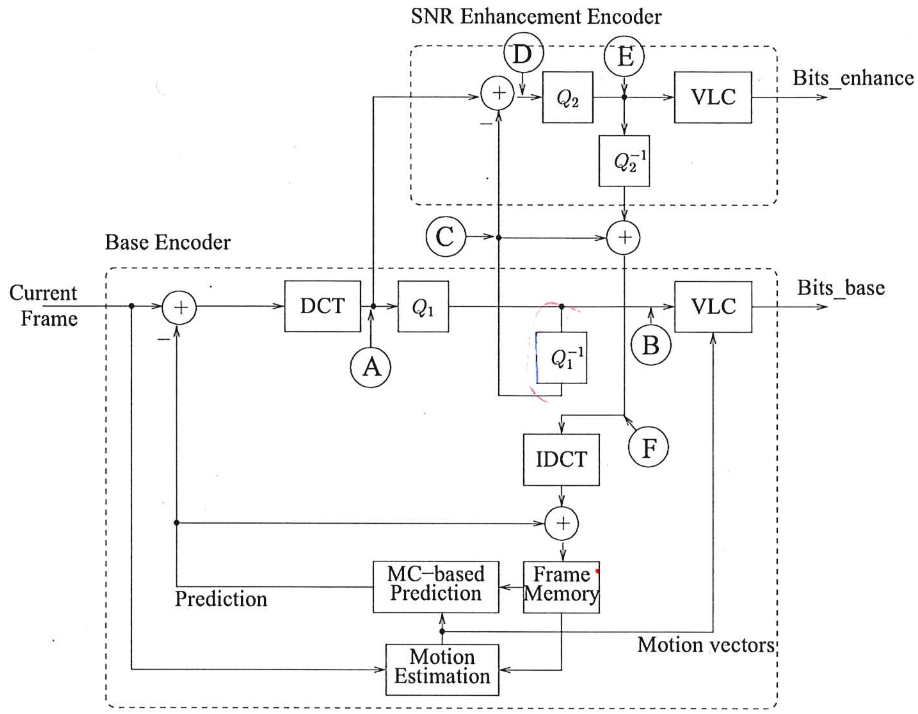


Figure 2: MPEG-2 Encoder for SNR Scalability

var. bit-rate / video qual.

3 (a) Why is *scalability* an important issue in Video Compression? adapt to different networks & devices

7 (b) Describe how *SNR Scalability* works.

10 (c) In the figure above, 6 checkpoints (i.e., A, B, C, D, E, F) are indicated.

Assume the block size for transform coding is 4×4, and quantization is done by $F'(u,v) = round(\frac{F(u,v)}{Q(u,v)})$. The quantization matrices are:

$$\mathbf{Q_1} = \begin{pmatrix} 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 10 \end{pmatrix}, \quad \text{and} \quad \mathbf{Q_2} = \begin{pmatrix} 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 \\ 2 & 2 & 2 & 2 \end{pmatrix}$$

If we use $\mathbf{A}$ to indicate the $4{\times}4$ block at checkpoint A, and $\mathbf{A} = \begin{pmatrix} 3 & 25 & -12 & 0 \\ 7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$,

show all the numbers observed in the other 5 checkpoints, i.e., **B**, **C**, **D**, **E**, and **F**.

B:
$$\begin{pmatrix} 0 & 3 & -1 & 0 \\ 1 & & \emptyset & \end{pmatrix}$$

C:
$$\begin{pmatrix} 0 & 30 & -10 & 0 \\ 10 & & \emptyset & \end{pmatrix}$$

D:
$$\begin{pmatrix} 3 & -5 & -2 & 0 \\ -3 & & \emptyset & \end{pmatrix}$$

E:
$$\begin{pmatrix} 2 & -3 & -1 & 0 \\ -2 & & \emptyset & \end{pmatrix}$$

F:
$$\begin{pmatrix} 4 & 24 & -12 & 0 \\ 6 & & \emptyset & \end{pmatrix}$$