EE5351 Digital Video Coding

INSTRUCTOR: Dr. K.R. Rao

Summer 2007, Final

Tuesday, 7 August 2007

6:00 – 7:50 PM (1 hour and 50 minutes)

(CLOSE BOOK, CLOSE NOTES)

INSTRUCTIONS:

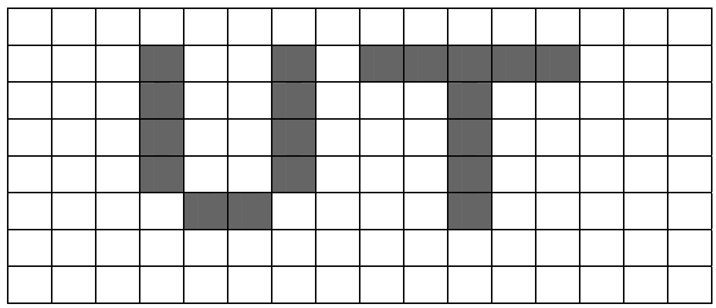
1. Close books and close notes.
2. Please show all the steps in your works.
4. You can work problems in any order.
   At the end please rearrange as 1, 2, 3, 4, and 5.
5. Please print your name and student ID.
6. No cheating, no talking.

Name____________________________

Student ID_______________________

[20 Points][**Problem 1**]

Encode the binary image (8×16 pixels) which is shown as below using the modified Huffman scheme (using the attached code table in the next page). The first pixel is an imaginary white pixel assumed to be the left of first actual pixel.



t = terminating code, $t = 1, 2, \ldots, 63$

$r_l = 64m + t$, m = make up code $0, 1, \ldots, 27$

TABLE C.3 **Terminating black codes.** t

Code	Length	Run	Code	Length	Run	Code	Length	Run
0000110111	10	0	00000110111	11	22	000011011011	12	43
010	3	1	00000101000	11	23	000001010100	12	44
11	2	2	00000010111	11	24	000001010101	12	45
10	2	3	00000011000	11	25	000001010110	12	46
011	3	4	000011001010	12	26	000001010111	12	47
0011	4	5	000011001011	12	27	000001100100	12	48
0010	4	6	000011001100	12	28	000001100101	12	49
00011	5	7	000011001101	12	29	000001010010	12	50
000101	6	8	000001101000	12	30	000001010011	12	51
000100	6	9	000001101001	12	31	000000100100	12	52
0000100	7	10	000001101010	12	32	000000110111	12	53
0000101	7	11	000001101011	12	33	000000111000	12	54
0000111	7	12	000011010010	12	34	000000100111	12	55
00000100	8	13	000011010011	12	35	000000101000	12	56
00000111	8	14	000011010100	12	36	000001011000	12	57
000011000	9	15	000011010101	12	37	000001011001	12	58
0000010111	10	16	000011010110	12	38	000000101011	12	59
0000011000	10	17	000011010111	12	39	000000101100	12	60
0000001000	10	18	000001101100	12	40	000001011010	12	61
00001100111	11	19	000001101101	12	41	000001100110	12	62
00001101000	11	20	000011011010	12	42	000001100111	12	63
00001101100	11	21						

TABLE C.4 **Make-up black codes.** m

Code	Length	Run	Code	Length	Run
0000001111	10	64	0000001110011	13	960
000011001000	12	128	0000001110100	13	1024
000011001001	12	192	0000001110101	13	1088
000001011011	12	256	0000001110110	13	1152
000000110011	12	320	0000001110111	13	1216
000000110100	12	384	0000001010010	13	1280
000000110101	12	448	0000001010011	13	1344
0000001101100	13	512	0000001010100	13	1408
0000001101101	13	576	0000001010101	13	1472
0000001001010	13	640	0000001011010	13	1536
0000001001011	13	704	0000001011011	13	1600
0000001001100	13	768	0000001100100	13	1664
0000001001101	13	832	0000001100101	13	1728
0000001110010	13	896			

TABLE C.5 **Extended make-up codes (black and white).**

Code	Length	Run
00000001000	11	1792
00000001100	11	1856
00000001101	11	1920
000000010010	12	1984
000000010011	12	2048
000000010100	12	2112
000000010101	12	2176
000000010110	12	2240
000000010111	12	2304
000000011100	12	2368
000000011101	12	2432
000000011110	12	2496
000000011111	12	2560

For larger paper width up to A3 in size

Modified Huffman (MH) Code

Modified Huffman Code (MH) for G3 fascimile (ITU-T)

Codes for Facsimile Encoding

TABLE C.1 **Terminating white codes.** t

Code	Length	Run	Code	Length	Run	Code	Length	Run
00110101	8	0	0010111	7	21	00101011	8	42
000111	6	1	0000011	7	22	00101100	8	43
0111	4	2	0000100	7	23	00101101	8	44
1000	4	3	0101000	7	24	00000100	8	45
1011	4	4	0101011	7	25	00000101	8	46
1100	4	5	0010011	7	26	00001010	8	47
1110	4	6	0100100	7	27	00001011	8	48
1111	4	7	0011000	7	28	01010010	8	49
10011	5	8	00000010	8	29	01010011	8	50
10100	5	9	00000011	8	30	01010100	8	51
00111	5	10	00011010	8	31	01010101	8	52
01000	5	11	00011011	8	32	00100100	8	53
001000	6	12	00010010	8	33	00100101	8	54
000011	6	13	00010011	8	34	01011000	8	55
110100	6	14	00010100	8	35	01011001	8	56
110101	6	15	00010101	8	36	01011010	8	57
101010	6	16	00010110	8	37	01011011	8	58
101011	6	17	00010111	8	38	01001010	8	59
0100111	7	18	00101000	8	39	01001011	8	60
0001100	7	19	00101001	8	40	00110010	8	61
0001000	7	20	00101010	8	41	00110011	8	62
						00110100	8	63

Runlength $r_l = 64m + t$, ($t = 0, 1, \cdots, 63$ & $m = 1, 2, \cdots, 27$)

m = make up code

t = terminating code

TABLE C.2 **Make-up white codes.** m

Code	Length	Run	Code	Length	Run
11011	5	64	011010100	9	960
10010	5	128	011010101	9	1024
010111	6	192	011010110	9	1088
0110111	7	256	011010111	9	1152
00110110	8	320	011011000	9	1216
00110111	8	384	011011001	9	1280
01100100	8	448	011011010	9	1344
01100101	8	512	011011011	9	1408
01101000	8	576	010011000	9	1472
01100111	8	640	010011001	9	1536
011001100	9	704	010011010	9	1600
011001101	9	768	011000	6	1664
011010010	9	832	010011011	9	1728
011010011	9	896			

End of line code (EOL) Black or white

000 000 000 001

[20 Points][**Problem 2**]

In CALIC, refinement to initial prediction $\hat{X}$ is as follows. Form the vector $[N, W, NW, NE, NN, WW, 2N - NN, 2W - WW]$. Compare each component of it's vector with $\hat{X}$ and set each component to '1' if it is less than $\hat{X}$. Otherwise set to '0'.

Show clearly that because of the dependence of the various components, there are only 144 possible configurations in this vector.

			NN	NNE	
		NW	N	NE	
	WW	W	$\boldsymbol{X}$		

Figure: Labeling the neighbors of pixel X

[20 Points][**Problem 3**]

Given the (constraint) average bit rate $R = \frac{1}{M}\sum_{k=1}^{M} R_k$, where M is the number of subbands, R_k is average number of *bpp* (bit per pixel) for subband *k*. Minimize the total reconstruction error $\sigma_R^2 = \alpha\sum_{j=1}^{M} 2^{-2R_j}\sigma_{\theta j}^2$, where $\sigma_{\theta j}^2$ is the reconstruction error variance for the *j*-th subband, subject to the constraint.

Show that $R_k = R + \frac{1}{2}\log_2 \frac{\sigma_{\theta k}^2}{\prod_{j=1}^{M}\left(\sigma_{\theta j}^2\right)^{\frac{1}{M}}}$

In the derivation steps,

[5 Points] Show $\frac{\partial J}{\partial R_k}$

[5 Points] Show λ (Lagrange variable) in terms of M, α, $\sigma_{\theta k}^2$, and R.

Make the derivation very clear. Show all steps.

Hints:

Set up the minimization problem in terms of Lagrange multiplier as,

$$J = \alpha\sum_{j=1}^{M} 2^{-2R_j}\sigma_{\theta j}^2 - \lambda\left[R - \frac{1}{M}\sum_{j=1}^{M} R_j\right]$$

$$d\left(a^u\right) = a^u\left(\ln a\right)du$$

[20 Points][**Problem 4**]

A sample image (8×8 pixels) is shown in Table. Both LPF and HPF are given, decompose the sample image into 2D four equal subbands. Identify the LL, LH, HL, and HH subbands. Apply reflection of pixel intensities at the borders.

Table: A sample image (8×8 pixels)

10	14	10	12	14	8	14	12
10	12	8	12	10	6	10	12
12	10	8	6	8	10	12	14
8	6	4	6	4	6	8	10
14	12	10	8	6	4	6	8
12	8	12	10	6	6	6	6
12	10	6	6	6	6	6	6
6	6	6	6	6	6	6	6

LPF (Averaging filter): $y_n = \dfrac{x_n + x_{n-1}}{2}$

HPF (Differencing filter): $z_n = \dfrac{x_n - x_{n-1}}{2}$

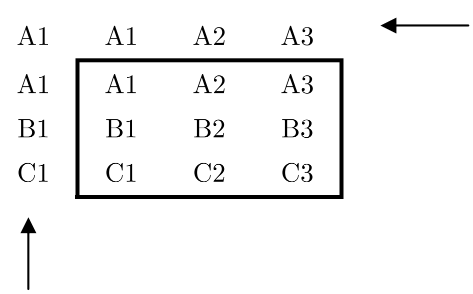


Figure: Example of row reflection and column reflection at the border of an (3×3) pixel image

[20 Points][**Problem 5**]

(5.1)[10 Points] Show that the symmetric low pass filter

$h_n = h_{N-1-n} \quad, n = 0,1,\cdots,\frac{N}{2}-1$ is linear phase for length 8. ($N = 8$, $n = 0,1,2,...,7$)

(5.2)[10 Points] Show that the high pass filter $h_{HPF}(n) = (-1)^n h_{LPF}(n)$ is also linear phase for length 8, ($N = 8$, $n = 0,1,2,...,7$). h_{LPF} is the low pass filter given in (5.1)

END OF TEST QUESTIONS