NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2015-2016

EE6427 – VIDEO SIGNAL PROCESSING

November/December 2015 Time Allowed: 3 hours

INSTRUCTIONS

1. This paper contains 5 questions and comprises 6 pages.
2. Answer all 5 questions.
3. All questions carry equal marks.
4. This is a closed-book examination.

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1. The source S = {a, b, c, d, e, f} has the corresponding probabilities

$$P = \{0.4, 0.22, 0.15, 0.12, 0.1, 0.01\}.$$

(a) What are the Huffman code words appropriate for the source S?

Note: please assign "0" to the higher probability side and "1" to the lower probability side of each combination operation.

Calculate the average number of bits for Huffman code words.

(7 Marks)

(b) Use the Huffman code defined in part (a) to encode the message "bad". If the bitstream of the encoded message is received with one bit error in the first bit of the bitstream, determine the decoded message.

(3 Marks)

(c) The source S is assigned to the segments of the first interval in the following manners, where a = [0, 0.4), b = [0.4, 0.62), c = [0.62, 0.77), d = [0.77, 0.89), e = [0.89, 0.99), and f = [0.99, 1]. Show the divisions of the interval for arithmetic encoding of the message "bad".

(7 Marks)

Note: Question no. 1 continues on page 2

(d) Use the interval defined in part (c) to decode the first three letters in the message of arithmetic code "0.75".

(3 Marks)

2. A transform matrix A for a 4 x 4 transform is shown in Figure 1.

$$A = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix}$$

Figure 1

Let X is 4 x 4 block of sample from an image as shown in Figure 2.

$$X = \begin{bmatrix} 20 & 20 & 5 & 5 \\ 20 & 20 & 5 & 5 \\ 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \end{bmatrix}$$

Figure 2

(a) Calculate the two-dimensional transform of the block X based on transform matrix A by using row column decomposition method.

(8 Marks)

(b) Apply a quantizer of 15 to DC coefficient and apply a quantizer of 70 to all AC coefficients obtained in part (a). Calculate the quantized transform coefficients, and show the quantized transform coefficients after zigzag scanning.

(4 Marks)

(c) Huffman codes for DC coefficient and AC coefficients are defined in Table 1 and Table 2 respectively in page 3 where EOB is transmitted after the last non-zero coefficient. EOB is omitted in case the final element of the vector is non-zero.

Note: If the required codewords are not shown in the tables, please answer "codeword not found"

(i) Apply the Huffman codes in Table 1 to encode the quantized DC coefficient obtained in part (b).

Note: Question no. 2 continues on page 3

Table 1

DC Coefficients	Size	Huffman codes for Size
0	0	00
-1,1	1	010
-3,-2,2,3	2	011
-7,…,-4,4,…,7	3	100
-15,…-8,8,…,15	4	101
-31,…,-16,16,…,31	5	110
⋮	⋮	⋮

(ii) Apply run length coding to encode the quantized AC coefficients obtained in part (b), and follow by using the Huffman codes in Table 2 to encode the results obtained. State your assumptions, if any.

Table 2

(Skip,Size)	Huffman Codes	(Skip,Size)	Huffman Codes
(0,1)	00	(0,6)	1111000
(0,2)	01	(1,3)	1111001
(0,3)	100	(5,1)	1111010
(EOB)	1010	(6,1)	1111011
(0,4)	1011	(0,7)	11111000
(1,1)	1100	(2,2)	11111001
(0,5)	11010	(7,1)	11111010
(1,2)	11011	(8,1)	111111000
(2,1)	11100	(3,2)	111110111
(3,1)	111010	(4,2)	1111111000
(4,1)	111011	⋮	⋮

(8 Marks)

3. (a) A video encoder is used to compress a 4:2:0 chroma subsampling video with a frame resolution of 800 x 600, frame rate of 30 frames per second in progressive mode, 10 bits per pixel, and open Group of Picture (GOP) structure starting with a B frame as in the following display order,

$$B_1\ B_2\ I_3\ B_4\ B_5\ P_6\ B_7\ B_8\ P_9\ B_{10}\ B_{11}\ P_{12}.$$

The video is compressed at the required quality with an average I-frame compression ratio of 10:1, an average P-frame compression ratio of 30:1, and an average B-frame compression ratio of 70:1. Assume that the compression ratios include all required headers.

(i) Determine the encoding order of the GOP.

(ii) Compute the average bit rate for the encoded video.

(10 Marks)

(b) In motion estimation, half-pel accurate motion vectors can be obtained by interpolating the current frame and the reference frame by a factor of two and followed by using the block matching algorithms for motion estimation. With the help of diagrams, explain steps to obtain half-pel accurate motion vector, and calculate all the half-pel values of a 4 x 4 image block as shown in Figure 3.

$$\begin{bmatrix} 11 & 12 & 13 & 14 \\ 15 & 15 & 15 & 15 \\ 16 & 16 & 17 & 17 \\ 18 & 19 & 19 & 19 \end{bmatrix}$$

Figure 3

(10 Marks)

4. (a) Draw a simplified block diagram of MPEG-4 video encoder with the following function blocks, where input is VOP and output is bitstream.

- Context-based arithmetic encoding (CAE)
- Shape motion compensation (Shape MC)
- Shape motion estimation (Shape ME)
- Shape memory
- Discrete Cosine Transform (DCT)
- Inverse DCT (IDCT)
- Quantization (Q)
- Inverse quantization (IQ)
- Motion estimation (ME)
- Motion compensation (MC)
- VOP memory
- Variable length coding (VLC)
- Intra DC & AC prediction
- Padding
- Multiplexer (MUX)

(10 Marks)

(b) A simplified pattern of content-based arithmetic encoding (CAE) is shown in Figure 4. The corresponding probability table of the pixel "X" predicted as "0" is given in Table 3. Use the content-based arithmetic encoding scheme to encode the 4 pixels in an underlined 2-by-2 block as shown in Figure 5. How many bits are required to represent this block?

C3	C2	C1
C0	X	

Figure 4

0	0	1	1	
0	***1***	***1***	0	
1	***1***	***0***	0	

Figure 5

Table 3

C3 C2 C1 C0	0000	0001	0010	0011	0100	0101	0110	0111
Probability	0.9	0.1	0.5	0.1	0.5	0.1	0.4	0.1
C3 C2 C1 C0	1000	1001	1010	1011	1100	1101	1110	1111
Probability	0.9	0.8	0.5	0.4	0.9	0.4	0.9	0.1

(10 Marks)

5. (a) A 4 x 4 image block is given in Figure 6.

46	14	37	41
46	14	39	43
36	36	15	15
36	36	13	13

Figure 6

Show the two-stage Haar Wavelet Transform decomposition of the image block. Show the coefficients output from each stage of decomposition.

(10 Marks)

(b) Applying the embedded zerotree wavelet (EZW) coding scheme to the results obtained in part (a) and show the encoding result. Note that four symbols in dominant pass for EZW are T (zerotree root), Z (isolated zero), P (positive) and N (negative).

(10 Marks)

END OF PAPER