NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2017-2018

EE6427 – VIDEO SIGNAL PROCESSING

November/December 2017 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. (a) The source S = {a, b, c, d, e, f, g} has the corresponding probabilities P = {0.35, 0.2, 0.15, 0.11, 0.1, 0.07, 0.02}

   (i) What are the Shannon-Fano code words appropriate for the source S?

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

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

   (12 Marks)

   (b) The source S = {a, b, c, d, e, f, g} is assigned to the segments of the first interval in the following manner: a = [0, 0.35), b = [0.35, 0.55), c = [0.55, 0.7), d = [0.7, 0.81), e = [0.81, 0.91), f = [0.91, 0.98) and g = [0.98, 1). Show the divisions of the interval for arithmetic encoding of the message "bcd".

   (8 Marks)

2. Consider a two-dimensional Discrete Cosine Transform as defined in Equation (1) in the following. Let X be a 4x4 block of image samples as shown in Figure 1.

$$Y(u,v) = \sum_{j=0}^{3}\sum_{i=0}^{3} X(i,j)\cos\left[\frac{(2i+1)u\pi}{8}\right]\cos\left[\frac{(2j+1)v\pi}{8}\right] \quad \text{---------- (1)}$$

$u, v = 0, 1, 2, 3$

$$X = \begin{bmatrix} 40 & 20 & 40 & 20 \\ 40 & 20 & 40 & 20 \\ 40 & 20 & 40 & 20 \\ 40 & 20 & 40 & 20 \end{bmatrix}$$

Figure 1

(a) Compute the two-dimensional Discrete Cosine Transform of the block X by using row column decomposition method.

(10 Marks)

(b) Apply a quantizer of 30 to DC coefficient and apply a quantizer of 60 to all AC coefficients. Calculate the quantized transform coefficients, and show the quantized transform coefficients after zigzag scanning.

(3 Marks)

(c) Huffman codes for DC coefficient and AC coefficients are defined in Table 1 and Table 2 on page 3 respectively where EOB stands for End Of Block. (Note: If the required codewords are not shown in the tables, please answer "codeword not found")

(i) Apply the Huffman codes in Table 1 on page 3 to encode the quantized DC coefficient obtained in part (b).

(ii) Apply run length code to encode the quantized AC coefficients obtained in part (b), and follow by using the Huffman codes in Table 2 on page 3 to encode the results obtained. State your assumptions, if any.

(7 Marks)

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
⋮	⋮	⋮

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	⋮	⋮

3. (a) In block based video motion estimation, three-step search with a search area of ±7 pixels is considered to form the prediction of the current frame from the reference frame. With the help of simple diagrams, describe the steps of three-step search.

(5 Marks)

(b) If a search area of ±7 pixels is considered to form the prediction of the current frame from the reference frame and the block size of the frame is 8x8 pixels. Calculate the number of multiplications for each block for three-step search if the distortion criterion is mean square error (MSE) and mean absolute error (MAE) respectively.

(6 Marks)

(c) A block of 2x2 pixels in the current frame is shown in Figure 2 and its co-located block in the reference frame is shown in the shaded area in Figure 3. Within a search window of ± 1 pixels, find the best-matched motion vector and the corresponding block in Figure 3, if distortion criterion is based on MAE.

70	50
30	50

Figure 2

55	55	60	40
50	30	40	45
45	45	65	35
30	45	45	40

Figure 3

(9 Marks)

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

- Shape motion estimation (Shape ME)
- Shape motion compensation (Shape MC)
- Shape memory (SM)
- Context-based arithmetic encoding (CAE)
- Variable length coding (VLC)
- Multiplexer (MUX)
- Shape motion vector (shape MV)

(10 Marks)

Note: Question No. 4 continues on page 5

(b) A simplified pattern of inter context-based arithmetic encoding (interCAE) for shape coding is shown in Figure 4 and Figure 5 where "X" and "c4" are co-located pixels in current block and motion compensated (MC) block respectively. The corresponding probability table of the pixel "X" predicted as "0" is given in Table 3. Assuming that the shape motion vector is (0,0), use the inter context-based arithmetic encoding scheme to encode the 4 pixels in an underlined 2-by-2 block as shown in the Figure 6 on page 5, where Figure 7 is the corresponding MC block. Show the steps of interCAE. How many bits are required to represent the underlined 2-by-2 block?

C3	C2	C1
C0	X	

Figure 4

C4

Figure 5

Table 3

C4 C3 C2 C1 C0	00000	00001	00010	00011	00100	00101	00110	00111
Probability	0.9	0.2	0.5	0.1	0.5	0.1	0.4	0.1
C4 C3 C2 C1 C0	01000	01001	01010	01011	01100	01101	01110	01111
Probability	0.9	0.8	0.5	0.4	0.8	0.1	0.7	0.1
C4 C3 C2 C1 C0	10000	10001	10010	10011	10100	10101	10110	10111
Probability	0.9	0.3	0.9	0.2	0.6	0.5	0.2	0.1
C4 C3 C2 C1 C0	11000	11001	11010	11011	11100	11101	11110	11111
Probability	0.9	0.6	0.9	0.5	0.9	0.5	0.8	0.1

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

Figure 6

0	0	0	1
0	0	1	1
0	1	1	0

Figure 7

(10 Marks)

5. (a) A 4 × 4 image block is given in Figure 8.

35	29	31	31
35	29	25	25
32	28	16	16
30	30	12	12

Figure 8

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

(10 Marks)

17	0	0	0
-8	0	0	0
0	-1	0	1
0	-1	0	2

Figure 9

(b) A two-level discrete wavelet transform decomposition result is shown in Figure 9. Applying the embedded zerotree wavelet (EZW) coding scheme to the wavelet coefficients in figure 9. Show the output for each pass. Note that four symbols in dominant pass for EZW are T (zerotree root), Z (isolated zero), P (positive) and N (negative), and Huffman code to represent the symbol are T: 0, Z: 10, N: 110, P: 1110. How many bits are required to represent coefficients?

(10 Marks)

END OF PAPER

EE6427 VIDEO SIGNAL PROCESSING

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.