NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2020-2021

EE6427 – VIDEO SIGNAL PROCESSING

November / December 2020 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 5 pages.
2. Answer all 4 questions.
3. All questions carry equal marks.
4. This is a closed book examination.
5. Unless specifically stated, all symbols have their usual meanings.

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1. (a) Consider a one-dimensional transform 'T' whose basis function is shown in Figure 1, and its inverse transform is identical to forward transform.

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

Figure 1

A grey level intensity matrix of a 4 × 4 image block is shown in Figure 2.

$$\begin{bmatrix} 60 & 40 & 30 & 30 \\ 60 & 40 & 40 & 30 \\ 60 & 60 & 40 & 40 \\ 70 & 60 & 40 & 40 \end{bmatrix}$$

Figure 2

Compute the two-dimensional transform based on 'T' for the image block shown in Figure 2 by using the row-column decomposition method.

(7 Marks)

Note: Question No. 1 continues on page 2.

(b) Apply the quantization matrix in Figure 3 to the coefficients obtained in part (a). Calculate the quantized transform coefficients, and show the quantized transform coefficients after zigzag scanning.

$$\begin{bmatrix} 16 & 20 & 16 & 20 \\ 20 & 25 & 20 & 25 \\ 16 & 20 & 16 & 20 \\ 20 & 25 & 20 & 25 \end{bmatrix}$$

Figure 3

(3 Marks)

(c) Apply the inverse quantization to the coefficients obtained in part (b), and compute the two-dimensional inverse transform of the inverse-quantized coefficients.

(7 Marks)

(d) Reversible Variable Length Code (RVLC) is an error resilience tool for MPEG-4 video. Explain how RVLC can help to maintain the video quality in case of transmission error occurring in an MPEG-4 video bitstream. Please indicate the position of RVLC used in an MPEG-4 error resilient video packet.

(8 Marks)

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

(12 Marks)

(b) A simplified pattern of inter context-based arithmetic encoding (interCAE) is shown in Figure 4 and Figure 5 on page 3 where "X" and "C4" are co-located pixels in the current block and motion compensated (MC) block, respectively. The corresponding probability table of the pixel "X" predicted as "0" is given in Table 1 on page 3. Assume that Figure 6 on page 3 is the current shape image, Figure 7 on page 3 is the corresponding reference shape image, and the shape motion vector is (0,1). Use the interCAE scheme to encode the 4 pixels in the underlined 2 x 2 block as shown in Figure 6 on page 3. What is the binary codeword used to represent this 2 x 2 block?

Note: Question No. 2 continues on page 3.

C3	C2	C1
C0	X	

Figure 4

C4

Figure 5

Table 1

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

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

Figure 6

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

Figure 7

(13 Marks)

3. (a) What is the result of applying median filtering to the 1-D image [8 70 6 2 3 7 1 3 20 18]? The size of the median filter is 3.

(4 Marks)

(b) Why is median filtering more effective than Gaussian filtering in eliminating salt-and-pepper noise?

(6 Marks)

(c) Three image kernels with size 3 x 3 named K1, K2 and K3 are given in Figures 8 to 10, respectively. A 6 x 6 image block, f, is shown in Figure 11. Perform the 2-D convolution between each of the individual kernels K1, K2, and K3, with the image block f to obtain 4 x 4 outputs (round your answers to the nearest integer). Describe the function of each kernel.

$$K1 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Figure 8

$$K2 = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Figure 9

$$K3 = \frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Figure 10

$$f = \begin{bmatrix} 10 & 10 & 10 & 10 & 10 & 10 \\ 10 & 10 & 10 & 20 & 20 & 10 \\ 10 & 10 & 20 & 20 & 20 & 10 \\ 20 & 20 & 20 & 20 & 20 & 10 \\ 20 & 20 & 20 & 20 & 20 & 10 \\ 20 & 20 & 20 & 20 & 20 & 10 \end{bmatrix}$$

Figure 11

(15 Marks)

4. (a) A 4 x 4 image block is given in Figure 12.

18	16	40	36
20	14	42	38
15	15	39	39
9	13	39	39

Figure 12

Note: Question No. 4 continues on page 5.

Show the two-level Haar Wavelet Transform decomposition of the 4 x 4 image block. Show the output coefficients from each level of decomposition.

(12 Marks)

(b) Apply the Embedded Zerotree Wavelet (EZW) coding scheme to the wavelet coefficients obtained in part (a) and show the encoding result. Note that four symbols in the dominant pass for EZW are T (zerotree root), Z (isolated zero), P (positive) and N (negative) respectively. If a fixed length code of 2-bit is used to represent each of the four symbols, how many bits are required to represent the coefficients?

(13 Marks)

END OF PAPER

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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.