NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2019-2020

EE6427 – VIDEO SIGNAL PROCESSING

November / December 2019 Time Allowed: 3 hours

INSTRUCTIONS

1. This paper contains 5 questions and comprises 4 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) Consider a one-dimensional forward transform 'U' and its inverse transform 'V' whose basis functions are shown in Figure 1 and Figure 2 respectively.

$$U = \frac{1}{2}\begin{bmatrix} a & a & a & a \\ b & c & -c & -b \\ a & -a & -a & a \\ c & -b & b & -c \end{bmatrix} \qquad V = \begin{bmatrix} a & b & a & c \\ a & c & -a & -b \\ a & -c & -a & b \\ a & -b & a & -c \end{bmatrix}$$

Figure 1 **Figure 2**

where $a = \frac{1}{\sqrt{2}}$ $b = \cos\left(\frac{\pi}{8}\right)$ $c = \cos\left(\frac{3\pi}{8}\right)$

A grey level intensity matrix of a 4x4 image block is shown in Figure 3.

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

Figure 3

Note: Question No. 1 continues on page 2.

Compute the two-dimensional transform based on 'U' for the block shown in Figure 3 on page 1 by using the row column decomposition method.

(9 Marks)

(b) Apply a quantizer of value 12 to all coefficients obtained in part (a). Calculate the quantized transform coefficients, and show the quantized transform coefficients after zigzag scanning.

(3 Marks)

(c) Apply the inverse quantization to the coefficients obtained in part (b), and compute the two-dimensional inverse transform based on 'V' for the inverse quantized coefficients.

(8 Marks)

2. The source S = {a, b, c, d, e, f} has the corresponding probabilities of occurrences P = {0.36, 0.07, 0.14, 0.12, 0.1, 0.21}.

(a) Design a suitable set of Huffman code words for the source S. Note: assign "0" to the higher probability branch and "1" to the lower probability branch of each combination operation. Calculate the average number of bits for the designed Huffman code words.

(7 Marks)

(b) Use the Huffman codes defined in part (a) to encode the message "fed". 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, 0.36), b = [0.36, 0.43), c = [0.43, 0.57), d = [0.57, 0.69), e = [0.69, 0.79), and f = [0.79, 1). Show the divisions of the interval for arithmetic encoding of the message "fed".

(7 Marks)

(d) Use the segments defined in part (c) to decode the first three letters in the message of arithmetic code "0.25".

(3 Marks)

3. (a) A video encoder is used to compress a 4:2:2 chroma subsampling video with a frame resolution of 1024x768, frame rate of 30 frames per second in progressive mode, 8 bits per pixel, and open Group of Picture (GOP) structure starting with a B frame as shown in the following display order:

$B_1\ I_2\ B_3\ B_4\ P_5\ P_6\ B_7\ B_8\ P_9\ P_{10}\ B_{11}\ P_{12}$.

The video is compressed at the required quality that has an average I-frame compression ratio of 12:1, an average P-frame compression ratio of 35:1, 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) Calculate the average bit rate for the compressed video.

(10 Marks)

(b) In H.264 standard, multiple reference frames can be used for frame prediction and error resilience.

(i) Describe what are the advantage and disadvantage of using multiple reference frames in terms of encoding performance.

(ii) Describe what are the advantage and disadvantage of using multiple reference frames in terms of error resilience.

(10 Marks)

4. (a) Draw a block diagram of MPEG-2 SNR scalability encoding with the following functional blocks, where the input is video and the output is base layer bitstream and enhancement layer bitstream respectively.

- Discrete Cosine Transform (DCT)
- Inverse Discrete Cosine Transform (IDCT)
- Quantization (Q)
- Inverse Quantization (IQ)
- Motion Estimation (ME)
- Motion Compensation (MC)
- Variable Length Coding (VLC)
- Frame Memory (FM)

(12 Marks)

Note: Question No. 4 continues on page 4.

(b) Describe two advantages of using scalable coding such as MPEG-2 scalability when compared with non-scalable coding in a real-time video transmission system.

(8 Marks)

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

42	50	27	21
44	48	25	23
34	38	20	20
32	32	20	20

Figure 4

Show the two-level Haar Wavelet Transform decomposition of the 4x4 image block. Show the coefficients output from each level of decomposition.

(10 Marks)

(b) A two-level discrete wavelet transform decomposition result is shown in Figure 5. Apply the EZW coding scheme to the wavelet coefficients in Figure 5 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.

35	−4	0	0
13	2	0	0
0	0	0	−1
1	1	0	−2

Figure 5

(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.