NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2020-2021

EE6403 – DISTRIBUTED MULTIMEDIA SYSTEMS

April / May 2021 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.
5. Unless specifically stated, all symbols have their usual meanings.

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1. (a) In a text messaging system, only the first 4 Roman alphabets (A, B, C and D) are used to encode the messages. The probabilities of occurrences for these alphabets (symbols) are given in Table 1.

Table 1

Symbol	A	B	C	D
Probability of occurrence	0.36	0.30	0.22	0.12

(i) Design a suitable set of Huffman codewords to encode the symbols in Table 1. Your answer should clearly outline all the steps and calculations involved.

(ii) A message X consists of 8,000 symbols with the probabilities of occurrences given in Table 1. The message is to be compressed using the Huffman codewords designed in part (a)(i). Calculate the expected storage requirement of message X in bytes.

(10 Marks)

Note: Question No. 1 continues on page 2.

(b) In a second text messaging system, only the first 8 Roman alphabets (A, B, C, D, E, F, G and H) are used to encode the messages. The probabilities of occurrences for these alphabets (symbols) are given in Table 2, where p and q are positive real numbers. The codewords in Table 2 are used to encode the symbols.

Table 2

Symbol	A	B	C	D	E	F	G	H
Probability of occurrence	p	0.18	0.16	0.14	0.12	0.10	0.05	q
Codeword	01	111	110	101	100	001	0001	0000

Given that the average number of bits that is required to encode a symbol is 2.95 bits/symbol, find the values p and q. Based on your results, comment on whether the codewords in Table 2 are optimal in performing text compression.

(10 Marks)

2. The two-dimensional Discrete Cosine Transform (2D-DCT) of an $N \times N$ data matrix is given by:

$$S_{uv} = \alpha(u)\alpha(v)\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} s_{ij} \cos\frac{(2i+1)u\pi}{2N} \cos\frac{(2j+1)v\pi}{2N}, \qquad u, v = 0, \ldots, N-1$$

where

$$\alpha(k) = \begin{cases} \sqrt{\dfrac{1}{N}} & \text{for } k = 0 \\ \sqrt{\dfrac{2}{N}} & \text{for } k = 1, 2, \ldots, N-1 \end{cases}.$$

(a) Calculate the 2D-DCT of the following 4×4 image block A.

$$A = \begin{bmatrix} 10 & 0 & 0 & 10 \\ 10 & 0 & 0 & 10 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

(12 Marks)

Note: Question No. 2 continues on page 3.

(b) Two students discuss using different transform-based image compression techniques to compress a class of highly textured images with significant textures and edges.

(i) Student A suggests using the 2D-DCT to compress the images as he believes the 2D-DCT has good energy compaction capability. Discuss briefly whether you agree with his suggestion and justification.

(ii) Student B suggests using the Karhunen-Loeve Transform (KLT) to compress the images. Discuss briefly whether you agree that it is better to use the KLT over the DCT to compress these images.

(8 Marks)

3. (a) In a video application, a user chooses to use the following video formats to compress an action movie video that contains significant fast motions:

Compression standard: MPEG-2
Resolution of the luminance plane: 720×480 pixels
Color depth of every pixel in each luminance and chrominance plane: 8 bits/pixel
Chroma subsampling format: 4:2:2
Group-of-Picture (GOP) structure: IBBPBBPBB
Frame rate: 30 frames per second (fps)

The average compression ratios for the I-frames, P-frames, and B-frames of the video are assumed to be 10:1, 20:1, and 40:1, respectively. The duration of the video is 50 minutes.

(i) Calculate the storage requirement of the compressed video in bytes. State any assumption(s) you use in the calculation.

(ii) The user finds that when the compressed video is played on a 4K OLED TV, the overall viewing experience is not satisfactory. Suggest 3 ways to modify the video formats such that they will most likely be able to improve the viewing experience of the video on the TV.

(10 Marks)

(b) With the aid of a 16-QAM diagram, briefly explain the objective and basic principles of Quadrature Amplitude Modulation (QAM) in data communications.

(6 Marks)

(c) Briefly explain the key principles of virtual circuit switching in data communications.

(4 Marks)

4. (a) A data sequence 1001100 (most significant bit on the left) is to be coded and transmitted using the Cyclic Redundancy Check (CRC) with the generator polynomial sequence of P = 1101.

(i) Determine the transmitted codeword.
(ii) Calculate the remainder obtained using the CRC at the receiver if 2 transmission errors occur in the third and fourth bits (from the left) of the transmitted codeword obtained in part (a)(i).
(iii) Discuss briefly whether the CRC can detect the errors in part (a)(ii).

(14 Marks)

(b) Some video streaming applications use Content Distribution Networks (CDNs) in their operation. Briefly explain the roles of CDNs and list the advantages of CDNs over single data center in video streaming.

(6 Marks)

5. A company would like to develop a mobile app to perform bird image recognition. The mobile app will involve users taking bird images using mobile phone cameras, and then use a Deep Neural Network (DNN) to perform bird image recognition.

(a) The company suggests using a Convolutional Neural Network (CNN) for the application. With the aid of a diagram, list and briefly describe the main objectives of different layers in a CNN architecture.

(12 Marks)

(b) In the first possible system design, the company would like to develop the mobile app using a client-server model, where the proposed DNN will be located at the server. Briefly discuss the interaction between the server and clients in this case.

(4 Marks)

(c) In the second possible system design, the company would like the DNN to be located at the mobile phone so that the app does not require connection to a remote server. The company suggests using the VGG network to achieve the goal. Discuss briefly whether the VGG network is a suitable choice in this case.

(4 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.