UNIVERSITY OF LONDON

GOLDSMITHS COLLEGE

B.Sc. Examination 2012

Computing

IS53010A Resit Data Compression

Duration: 2 hours and 15 minutes

Date and time:

There are five questions in this paper. You should answer no more than three questions. Full marks will be awarded for complete answers to a total of three questions. Each question carries 25 marks. The marks for each part of a question are indicated at the end of the part in [.] *brackets.*

There are 75 marks available on this paper.

Electronic calculators must not be programmed prior to the examination. Calculators which display graphics, text or algebraic equations are not allowed.

THIS PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

Question 1

(a) Describe the main idea of *predictive encoding*. Suppose that the matrix below represents the pixel values (in decimal) of part of a grayscale image. Using the predictor $x = T$ in JPEG

T	S
Q	x?

, illustrate step by step how the predictive encoding algorithm may be applied to the matrix. [9]

$$\begin{matrix} 2 & 3 & 4 & 5 \\ 3 & 4 & 5 & 6 \\ 3 & 4 & 6 & 6 \\ 4 & 5 & 6 & 7 \end{matrix}$$

(b) Outline the *adaptive Huffman* coding algorithm and discuss the advantages of the approach over the static approach. Demonstrate how you would decode the binary string below by the adaptive Huffman decompression algorithm. Trace the states of the **input**, **output**, **alphabet** and the **tree structure** on each step. [16]

`0100001010100000101010001111101001000100000`.

[Hint: Your answer should be divided into coherent sections including encoding as well as the decoding.]

Question 2

(a) Consider the alphabet (A, B, C, D) of a source. Discuss the possibility of finding: [4]

i. A uniquely decodable binary code in which the codeword for A is of length 2, that for B of length 1 and for both C and D of length 3.
ii. A shorter variable length prefix code than the one described in (a)i.

Provide evidence or justification for your answers.

(b) Demonstrate, step by step, how the compression efficiency of the Shannon-Fano encoding can be improved by alphabet extension. Use, as an example, a binary alphabet (A, B) with the probability of A being 0.3. [9]

(c) Huffman coding can perform badly when it is applied to fax images. Discuss briefly, with the aid of an example, in what situation the bad performance may happen. For example, the canonical minimum-variance Huffman code is about 37% worse than its optimal when the probabilities of the pixels are $Pr(White) = 0.2$ and $Pr(Black) = 0.8$. Demonstrate step by step how this situation can be improved by grouping two symbols at a time from the source. [12]

Hint: $\log_{10} 2 \approx 0.3$; $\log_{10} 0.8 \approx -0.1$; $\log_{10} 0.2 \approx -0.7$.

Question 3

(a) Explain the meaning of each of the following terms and illustrate the corresponding concept by an example for each term. [6]

i. variable-to-variable model
ii. bi-level image

(b) Explain what an *optimal code* is in the context of data compression. Are Huffman codes optimal? Comment and justify, with the aid of an example, the truth of the following statement: [10]

"Huffman codes for text compression are not optimal in general but optimal for video compression."

(c) Demonstrate how to convert the decimal number 11 to its *reflected Grey code*. [4]

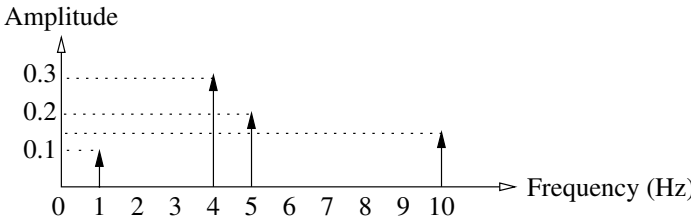
(d) What will be the output if the HDC algorithm is applied to the sequence below? Explain the meaning of each control symbol that you use. [5]

KKH␣␣␣␣␣␣␣␣␣T␣␣UU5555555␣␣BBBAA

Question 4

(a) John claims that the binary code (1, 01, 001, 010) is a prefix code since it satisfies the Kraft inequality. Check if the code indeed satisfies the Kraft inequality and explain what is wrong with John's claim. [5]

(b) Explain what is meant by *sampling* in the context of data compression. Consider the frequency spectrum diagram of an analogue signal in the figure below. What is the minimum sample rate that allows the reconstruction of the signal from the samples? [7]



(c) Following the approach of the LZ77 algorithm, demonstrate how to encode, step by step, the string `AABACCABBAAACCC`. Assume that the length of the history buffer $H = 6$ and the length of the lookahead buffer $L = 6$. [13]

Question 5

(a) A binary tree (0-1 tree) can be used to represent a code containing a few codewords of variable length. Consider each of the four codes for the characters A, B, C, D below and draw the binary trees for each code.

i. (0011, 0001, 110, 111)
ii. (110, 111, 0, 1)
iii. (0000, 001, 1, 0001)
iv. (0000, 0001, 001, 1)

For each tree drawn, comment on whether the code being represented by the binary tree is a prefix code, and justify your conclusion. [12]

(b) Explain, with a small example, what it means by *I picture* in the context of video compression? [5]

(c) Following the approach of LZW algorithm, decode step by step the tokens (`1, 1, 2, 1, 3, 3, 258, 259, 257, 261, 3`). Assume that the dictionary initially contains single characters A–Z and occupies cells at 1–256 only. Demonstrate the content changes of the main variables and the dictionary. [8]