DUBLIN CITY UNIVERSITY

SEMESTER ONE EXAMINATIONS 2007

MODULE: ***(Title & Code)***	Image and Video Compression EE554
COURSE:	Grad. Cert. in Electronic Systems (GCES) Grad. Dip. in Electronic (GDE) Masters in Electronic (MEN) Grad. Cert. in Telecommunications (GCTC) Grad. Dip. in Telecommunications Engineering (GTC) Masters in Telecommunications Engineering (MTC) Remote Access to Continuing Eng. Education (RAE)
YEAR:	5
EXAMINERS:	Dr. Noel E O'Connor, ext. 5078 Dr. David Sadlier, ext. 6008
TIME ALLOWED:	3 Hours
INSTRUCTIONS:	Please answer 4 questions. All questions carry equal marks

Requirements for this paper
Please tick (X) as appropriate

	Log Table
X	***Graph Paper***
	Attached Answer Sheet
	Statistical Tables
	Floppy Disk
	Actuarial Tables

THE USE OF PROGRAMMABLE OR TEXT STORING CALCULATORS IS EXPRESSLY FORBIDDEN

Please note that where a candidate answers more than the required number of questions, the examiner will mark all questions attempted and then select the highest scoring ones.

PLEASE DO NOT TURN OVER THIS PAGE UNTIL YOU ARE INSTRUCTED TO DO SO

Question 1

1(a) List and explain the **THREE** types of redundancy present in a video sequence and give an example of how each is exploited in a H.261 encoder in order to achieve compression. **[9 Marks]**

1(b) Describe the key features of the QCIF format for video sequences. What is the bandwidth required for a 1 minute QCIF sequence? List two features of this format that make it suitable for video compression applications. **[5 Marks]**

1(c) Shannon's noiseless coding theorem can be stated mathematically as: **[4 Marks]**

$$R(x) = H(x) + \epsilon$$

Define what is meant by $R(x)$, $H(x)$ and ϵ in this context. Explain in your own words what this theorem means. What is the practical implication of this theorem on a real-time video compression application such as video conferencing?

1(d) Briefly outline the two ways in which pixels are encoded in the ITU-T Group 3 facsimile compression standard. **[5 Marks]**

1(e) Describe **WHY** and **HOW** run-length coding is employed in cooperation with the Discrete Cosine Transform (DCT). **[2 Marks]**

[Total marks: 25]

Question 2

2(a) *"Huffman coding is only optimal when the probabilities of occurrence of the symbols in the information source are negative exponents of two"*. Show how this statement is true using **TWO** different information sources, each of which consists of **FOUR** symbols. **[8 Marks]**

> **HINT:** First define two different information sources. In each case, generate the Huffman codewords associated with the source. Then define a metric for measuring the efficiency of these codewords and compare the measure with the respective source's entropy.

2(b) Outline an algorithm for **ARITHMETIC ENCODING**. Illustrate the operation of this algorithm when used to encode the message '*aacb*', for the information source $\{a, b, c\}$ where $p_a = 0.5$,$p_b = 0.3$ and $p_c = 0.2$ and a, b, c are distributed along the real number line as in Figure 1. **[8 Marks]**

> **HINT:** You **DO NOT** have to sketch the successive narrowing of the interval on the real number line. Simply calculate the evolution of the interval bounds in the algorithm you outlined. You **DO NOT** have to calculate the final binary fraction obtained.

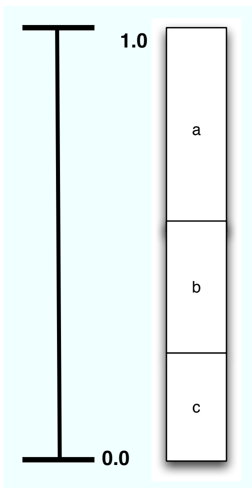

Figure 1: Distribution of a, b, c along the number line

Please turn over for parts (c) and (d)

2(c) Sketch a diagram to illustrate the concept of **HIERARCHICAL MOTION ESTIMATION** and briefly explain this process. **[5 Marks]**

2(d) *"A video compression standard need only define a decoder and a bitstream syntax".* Is this statement true or false? Explain the reason for your answer in either case. **[4 Marks]**

[Total marks: 25]

Question 3

3(a) State Fourier's Theorem for the sinusoidal-based expansion of periodic signals. Give a mathematical expression of Fouriers Theorem, explaining what each individual term of the expression represents - your explanation should make reference to comparing functions and/or inner products. **[8 Marks]**

3(b) Briefly state the two main ways in which Fouriers Theorem may be extended to the case of non-periodic functions. Explain how the construction of evenly/oddly symmetric periodic functions allows us to dictate the properties of Fourier Series expansions. (**HINT:** examine the standard mathematical expressions for calculating the Fourier coefficients (a_n and b_n), and consider the interval of definition of the functions to be $[-L/2, L/2]$, where L is the period). **[10 Marks]**

3(c) For a periodic function $y(x)$, under what conditions is its Fourier Series likely to converge faster than $\frac{1}{n^2}$? Use your answer to explain why the Fourier Series of the following function is unlikely to converge faster than $\frac{1}{n^2}$. **[7 Marks]**

$$y = \begin{cases} \frac{2Ax}{L} & \text{for } 0 \leq x < L/2 \\ 2A(1 - \frac{x}{L}) & \text{for } L/2 \leq x < L \end{cases}$$

Explain why half-range series with sine-only terms tend to have slower convergence than half-range series with cosine-only terms.

[Total marks: 25]

Question 4

4(a) Explain what is meant when a transform is said to exhibit the property of good 'energy compaction'. What is the relevance of energy compaction to the choice of the Discrete Cosine Transform used in JPEG, MPEG-1, and H.261 as opposed to (e.g.) the Discrete Sine Transform? Provide a mathematical expression for calculating the elements of the 1-D $N \times N$ Discrete Cosine Transform. Calculate the 1-D $N \times N$ DCT matrix for $N = 2$. Outline how the 1-D DCT can be extended to 2-D. **[9 Marks]**

4(b) Below is the Hadamard Transform matrix for $N = 4$. **[7 Marks]**

$$\mathbf{H}_4 = \frac{1}{2}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

Given that the Hadamard Transform is a non-sinusoidal based transform, explain how we can obtain a 'frequency interpretation' from its basis vectors. Figure 2 presents the 16 basis images of a 4×4 2-D Discrete Walsh-Hadamard Transform in a randomised order. Using the numbers assigned to each image, describe how they should be properly arranged, i.e. in their correct order of sequency.

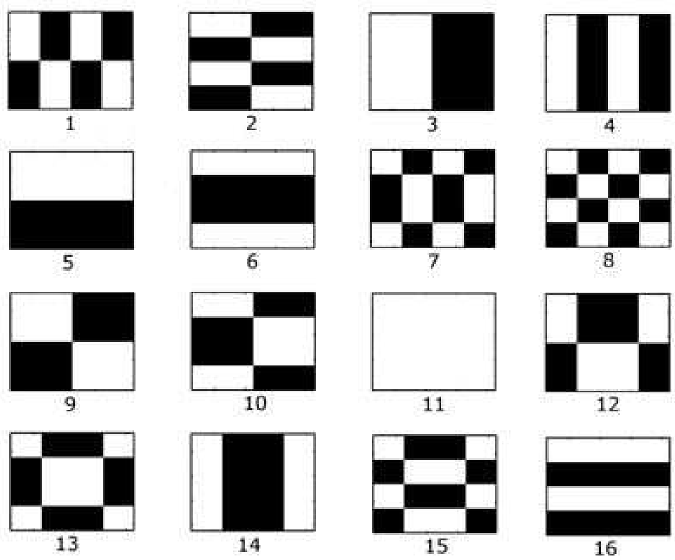

Figure 2: Basis images for a 4×4 2-D Discrete Walsh-Hadamard Transform

Please turn over for part (c)

4(c) It may be shown that, in representing a simple 2-D dataset (x_0, x_1), the gain derived from transform coding this data as opposed to straightforward PCM (Pulse Code Modulation) coding may be expressed as: **[9 Marks]**

$$\frac{\frac{1}{2}[\sigma_0^2 + \sigma_1^2]}{[\sigma_0^2\,\sigma_1^2]^{\frac{1}{2}}}$$

where σ^2 represents the variance of each transform coefficient. Explain why this is an important result in transform coding theory. What are the main issues surrounding the practicalities of bit allocation in a coding scheme? Outline a scheme for practical bit allocation that takes into account these issues. Your answer should make reference to two specific cases;

1. where fractional bit allocations are allowed;
2. where fractional bit allocations are not permitted.

[Total marks: 25]

Question 5

5(a) Sketch the high-level structure of a typical video encoder and briefly explain its operation. Indicate the **DECODING** processes in your diagram. Explain why decoding is necessary in a video encoder. **[9 Marks]**

> **HINT:** use the structure of a typical H.261 or H.263 encoder as the basis for your diagram.

5(b) What is meant by **TEMPORAL SCALABILITY** in the context of video encoding? Describe the different possibilities for configuring temporal scalability when used in conjunction with coding of arbitrarily-shaped objects in an MPEG-4 encoder. Illustrate the various possibilities with diagrams. In your diagrams you should illustrate the different types of Video Object Plane (I-/P-/B-VOP) in each layer. **[9 Marks]**

5(c) Explain how the DCT process should be modified in order to cope with coding the image data associated with a Binary Alpha Block (BAB) on the border of an object. **[5 Marks]**

5(d) Indicate a **NON-NORMATIVE** aspect of an MPEG-4 encoder that is peculiar to that standard (i.e. a non-normative process that is **NOT FOUND** in H.261, H.263 or MPEG-1 encoding). **[2 Marks]**

[Total marks: 25]