DUBLIN CITY UNIVERSITY

SEMESTER ONE EXAMINATIONS 2010-2011

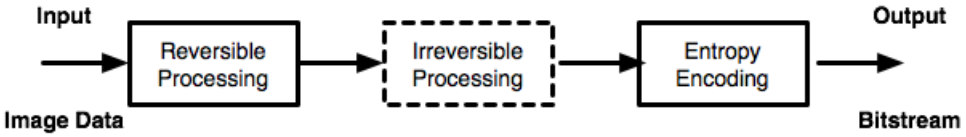
MODULE: (Title & Code)	EE554 Image and Video Compression
COURSE:	MEng in Electronic Systems (MEN) MEng in Telecommunications Engineering (MTC) Masters Engineering Qualifier Course (MEQ) Grad Cert. in Electronic Systems (GCES) Grad Cert. in Telecommunications Eng. (GCTC) Graduate Diploma in Electronic Systems (GDE) Grad Dip in Telecommunications Eng (GTC)
YEAR:	2010
EXAMINERS: (Including Telephone Nos.)	Prof Peter Ashburn Prof. Noel O'Connor, Ext no. 5078 Dr. David Sadlier, Ext no. 6830
TIME ALLOWED:	3 hours
INSTRUCTIONS:	Answer any FOUR questions

Please do not turn over this page until instructed to do so

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

QUESTION 1 [TOTAL MARKS: 25]

1(a) [14 Marks]



The diagram presents an abstraction of a generic image encoding process (ignoring the capture process itself) that consists of:

- A reversible process that acts on the input image data;
- An optional irreversible process that acts on the result;
- Entropy encoding to produce the output bitstream.

You are required to map this abstraction to:

1. The LOSSLESS mode of the JPEG image compression standard [7 marks]
2. The LOSSY mode of the JPEG standard [7 marks]

In each case, you should describe one example of each process referred to above and briefly describe its operation.

1(b) [8 Marks]

> "Huffman entropy encoding can be made more efficient at the cost of coding delay."

Explain what is meant by this statement by using the following simple information source, consisting of two symbols S_1 and S_2, whose probabilities of occurrence are shown in the table below, where S_1S_2 means "symbol S_1 occurs and is then followed by symbol S_2".

Symbol Sequence	S_1	S_2	S_1S_1	S_1S_2	S_2S_1	S_2S_2
Prob. of occurrence	0.8	0.2	0.64	0.16	0.16	0.04

1(c) [3 Marks]

Give an example of where arithmetic encoding is used in an international standard for image or video compression.

[End of Question 1]

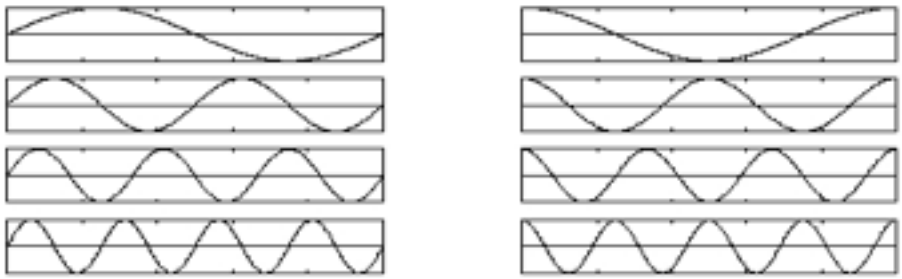
QUESTION 2 [TOTAL MARKS: 25]

2(a) [2 Marks]

A 1-dimensional discrete data vector of length N is to be transformed by an INVERTIBLE DISCRETE TRANSFORM. How many BASIS FUNCTIONS should the transform exhibit? How many DATA SAMPLES should each basis function contain?

2(b) [5 Marks]

The figure below shows a subset of the set of sine and cosine functions that constitute the basis functions of the Fourier Series (integer number of periods within a finite interval). What can be said about the similarity/dissimilarity of each function to the next? Explain the significance of the (dis)similarity of the functions in terms of the DECORRELATION POWER of Fourier Series.



2(c) [8 Marks]

The formulae for calculating the a_n and b_n Fourier Series coefficients are provided below. Also provided is the mathematical expression of Fourier's Theorem. By examining these formulae, explain how the EVEN/ODD SYMMETRY of $f(x)$ dictates the properties of its corresponding Fourier Series expansion.

> Hint: The symmetric integral about the origin of an ODD function equals ZERO.

$$a_n = \frac{2}{L}\int_{-\frac{L}{2}}^{\frac{L}{2}} f(x)\cos n\omega x \; dx$$

$$b_n = \frac{2}{L}\int_{-\frac{L}{2}}^{\frac{L}{2}} f(x)\sin n\omega x \; dx$$

$$f(x) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega x + \sum_{n=1}^{\infty} b_n \sin n\omega x$$

2(d) [6 Marks]

Below are expressions representing the OPTIMAL division of bits (n_0 and n_1) for a two transform coefficient system (X_0, X_1), where n_{av} is the average bit quota to be allocated between the coefficients. What does the symbol σ ('sigma') represent in these expressions? Explain the significance of this parameter with respect to how these expressions represent the OPTIMAL division of n_{av} bits across X_0 and X_1.

$$n_0 = n_{av} + \frac{1}{b}\log_2\frac{\sigma_0}{\sigma_1}$$

$$n_1 = n_{av} - \frac{1}{b}\log_2\frac{\sigma_0}{\sigma_1}$$

2(e) [4 Marks]

In bit-allocation theory, it may be shown that for a two-coefficient system (X_0, X_1), the GAIN derived from TRANSFORM-BASED CODING over PCM-BASED CODING (UNIFORM BIT ALLOCATION) may be expressed as shown below. Explain why this is an important result in transform coding theory.

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

[End of Question 2]

QUESTION 3 [TOTAL MARKS: 25]

3(a) [6 Marks]

An 8×8 pixel grid is transformed by the forward DISCRETE COSINE TRANSFORM (DCT), yielding a corresponding set of DCT COEFFICIENTS. What do these coefficients REPRESENT? To what extent has the 'size' of the data representation been REDUCED (i.e. compressed) by this process? In terms of the practicalities of data representation, is there any argument supporting the suggestion that the size of the representation has actually been INCREASED by this transformation? Explain your answers.

3(b) [4 Marks]

The figure below shows a 2-D 64-element QUANTIZATION TABLE to be used to compress image data according to the JPEG standard. In a figurative sense, what does each integer value represent with respect to the quantization process? Explain why there is large variation in the different values CHOSEN for this table.

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

3(c) [4 Marks]

Explain the concept of a SLICE in relation to MPEG-1 video coding. What would be the consequence of encoding MPEG-1 video frames with a LARGE number of SHORT slices, e.g. 132 slices per frame?

3(d) [11 Marks]

While carrying out MOTION ESTIMATION, an MPEG-1 video encoder calculated the following MOTION DISPLACEMENT VALUES for the horizontal (x-direction) components of the MOTION VECTORS of a SLICE consisting of 8 macroblocks:

4, 11, 30, 30, -15, -17, 28, 25

Assuming full_pel motion estimation was used, and assuming 30 was the largest horizontal motion displacement value calculated for the ENTIRE FRAME, use the table below to process the raw motion displacement values above according to MPEG-1 guidelines. Following this, demonstrate how an MPEG-1 decoder would use this table to REVERSE this processing towards reconstructing the ORIGINAL set of motion displacement values.

			Motion Vector Range $-16 \times f \leq dMD < 16 \times f$	
f_code	f	Modulus	full_pel=1	full_pel=0
1	1	32	-16 ... 15	-8 ... 7.5
2	2	64	-32 ... 31	-16 ... 15.5
3	4	128	-64 ... 63	-32 ... 31.5
4	8	256	-128 ... 127	-64 ... 63.5
5	16	512	-256 ... 255	-128 ... 127.5
6	32	1024	-512 ... 511	-256 ... 255.5
7	64	2048	-1024 ... 1023	-512 ... 511.5

[End of Question 3]

QUESTION 4 [TOTAL MARKS: 25]

4(a) [7 Marks]

Both motion estimation and motion compensation processes are required in a video encoder, but only one of these is necessary in a decoder.

1. Which process is necessary in the decoder? [1 mark]
2. Explain why both processes are necessary in the encoder. [3 marks]
3. Explain the implications of this for the design of an encoder compared to that of a decoder in terms of computational complexity requirements. [3 marks]

4(b) [7 Marks]

Describe a framework for HIERARCHICAL MOTION ESTIMATION, using diagrams to illustrate your answer. Outline TWO potential ADVANTAGES and ONE potential DISADVANTAGE of hierarchical motion estimation in terms of overall encoder design considerations.

4(c) [7 Marks]

> "In a block-based motion estimation search strategy, the best matching block always reflects the actual motion present in the scene."

Discuss this statement, making reference in your answer to the following considerations:

1. Whether the statement is TRUE or FALSE; [1 mark]
2. How motion is modeled in a typical block-based motion estimation process; [3 marks]
3. How a motion vector is calculated for a given block. [3 marks]

4(d) [4 Marks]

Motion estimation is a NON-NORMATIVE component of the H.263 video encoding standard. Explain what is meant by the term non-normative in this context, and discuss why this is an attractive aspect of the standard from a commercial/industrial perspective.

[End of Question 4]

QUESTION 5 [TOTAL MARKS: 25]

5(a) [12 Marks]

1. What is meant by the term SCALABILITY in the context of a video compression scheme? [2 marks]
2. Describe one ADVANTAGE and one DISADVANTAGE of scalability in the context of practical applications. [2 marks]
3. Describe TWO TYPES OF SCALABILITY that are supported by the MPEG-4 standard. In particular, explain how predictive coding should be configured in terms of the relationships between different types of VOPs to support scalable coding. Use diagrams to illustrate your answer. [8 marks]

5(b) [8 Marks]

Explain the method of binary SHAPE CODING employed in the MPEG-4 video compression standard as it applies to a given Binary Alpha Block (BAB). Use appropriate diagrams in order to illustrate your explanation.

5(c) [5 Marks]

> "Advances in image/video compression have been a contributor to the significant increase in the availability of digital media content in recent years, leading to information overload problems that require new technology solutions beyond pure compression."

Discuss this statement by describing what steps, beyond standardising compression approaches, the MPEG standards group has taken in an attempt to address the information overload problem.

[End of Question 5]

[END OF EXAM]