UNIVERSITY OF DUBLIN

TRINITY COLLEGE

FACULTY OF ENGINEERING, MATHEMATICS & SCIENCE

SCHOOL OF ENGINEERING

Electronic & Electrical Engineering

Senior Sophister
Engineering
Annual Examinations

Trinity Term, 2013

Digital Media Processing (4C8)

Date: 13th May 2013 **Venue: RH (136)** **Time: 9.30 – 11.30**

Dr. David Corrigan

Answer FOUR questions, including
Question ONE and any THREE of the remaining four questions.

All questions carry equal marks

Permitted Materials:

Calculator
Drawing Instruments
Mathematical Tables
Graph Paper

Compulsory

Q.1

(a) What is the necessary condition for the aliasing-free sampling of a 2D analogue signal?

[4 marks]

(b)

(i) Explain why it is necessary to use a low pass anti-aliasing filter when downsampling a discrete time signal. Use illustrations where necessary.

[6 marks]

(ii) Describe the appearance of a downsampled image when an anti-aliasing filter is applied and when it is not.

[2 marks]

(c) A continuous time 2D signal $f(x, y)$ is sampled at a sampling period of D samples per inch both vertically and horizontally to create a discrete time signal $f[m, n]$.

(i) A continuous time brick wall low pass filter with a frequency response:

$$H(\omega_1, \omega_2) = \begin{cases} D^2 & |\omega_1| < \Omega \text{ and } |\omega_2| < \Omega \\ 0 & \text{otherwise} \end{cases}$$

where Ω is the bandwidth of the filter. Show how this filter can be used to obtain the impulse response of an IIR discrete-time anti-aliasing filter for factor of 3 downsampling.

Note: The inverse Fourier Transform of $H(\omega_1, \omega_2)$ is

$$h(x, y) = \frac{D^2\Omega^2}{\pi^2}\operatorname{sinc}(\Omega x)\operatorname{sinc}(\Omega y)$$

[8 marks]

(ii) Explain the considerations involved in implementing a practical FIR filter based on the IIR filter derived in part **(i)**.

[5 marks]

Answer any three of the following four questions

Q.2

(a) Explain the relevance of Multiplexing, Sequencing, Synchronisation and Rate Control in the context of the MPEG compression standard.

[8 marks]

(b) An MPEG2 encoder is to use a GOP structure of IBBPBBPBBPBB to compress the video frames.

Explain what is meant by GOP structure and the letters I, B and P. In your answer, discuss the role of motion prediction in the encoding of the frames and make clear what data is compressed for each frame. How will the subsequent video frame be encoded?

Note: It can be assumed that the video sequence contains a luminance channel only.

[11 marks]

(c) The order in which frames of a GOP are decoded is different from the order in which they are displayed in. Assuming the GOP structure in part (b), determine the display and decode orders for the *GOP* structure in part (b) and explain why they are different.

[6 marks]

Q.3

(a) Define the terms *block size* and *search window* in the context of block matching motion estimation.

[4 marks]

(b) Outline an algorithm in pseudocode that implements full motion search block matching.

[10 marks]

(c) How many additions, multiplications and subtractions does it take to estimate the motion vectors for all of the blocks in a HDTV frame of resolution 1920×1080 when a block size of 16 and a search window of ± 20 used.

[6 marks]

(d) Motion detection is often employed in motion estimation to improve computational efficiency. Describe a simple motion detection algorithm that can be used in your full motion search block matching algorithm to decide whether a motion vector should be estimated for a block.

[5 marks]

Q.4

(a) Fig. Q.4b shows the 1 Level Haar Transform of the image in Fig. Q.4a. Identify the bands of the Haar Transform and justify your answer.

[4 marks]

(b) Show how the 1 level 2D Haar transform can be implemented as a filter bank. Explain how it can be extended to create a 3 level Haar Transform.

[8 marks]

(c) The 3 level Haar Transform is applied to an image of 720×576 pixels. The entropies for each subband after quantisation with a step size of 15 are indicated in Table Q.4.

(i) Calculate the minimum number of bits per pixel required to encode the quantised and transformed image.

[6 marks]

(ii) Explain why applying more levels of the Haar Transform will not result in significantly greater compression efficiency.

[4 marks]

Table Q.4

<table>
<tr><th colspan="2">Level and Band</th><th>Entropy (bits/coeff)</th><th colspan="2">Level and Band</th><th>Entropy (bits/coeff)</th></tr>
<tr><td rowspan="4">Level 3</td><td>LoLo</td><td>6.3956</td><td rowspan="2">Level 2</td><td>HiLo</td><td>1.2225</td></tr>
<tr><td>HiLo</td><td>3.0047</td><td>HiHi</td><td>0.636</td></tr>
<tr><td>LoHi</td><td>2.4226</td><td rowspan="3">Level 1</td><td>LoHi</td><td>0.6405</td></tr>
<tr><td>HiHi</td><td>1.69</td><td>HiLo</td><td>0.4516</td></tr>
<tr><td>Level 2</td><td>LoHi</td><td>1.6718</td><td>HiHi</td><td>0.0775</td></tr>
</table>

Fig. Q.4a

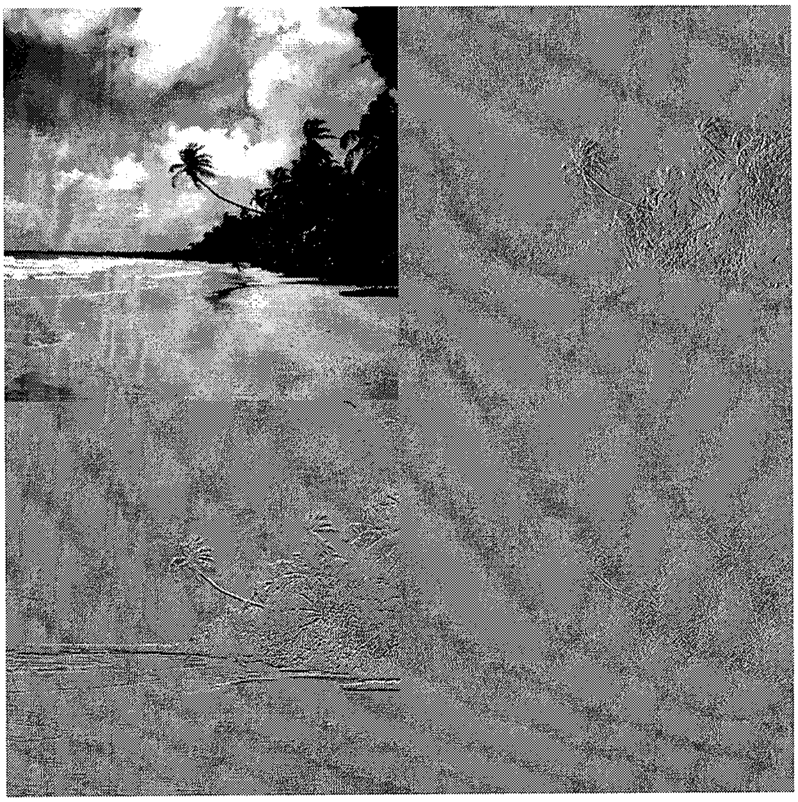

Fig. Q.4b

Q.5

(a) The 8-point DCT coefficient matrix for transforming an 8-element segment of a 1D signal is approximately given by:

$$T = \begin{pmatrix} 0.35 & 0.35 & 0.35 & 0.35 & 0.35 & 0.35 & 0.35 & 0.35 \\ 0.49 & 0.42 & 0.28 & 0.10 & -0.10 & -0.28 & -0.42 & -0.49 \\ 0.46 & 0.19 & -0.19 & -0.46 & -0.46 & -0.19 & 0.19 & 0.46 \\ 0.42 & -0.10 & -0.49 & -0.28 & 0.28 & 0.49 & 0.10 & -0.42 \\ 0.35 & -0.35 & -0.35 & 0.35 & 0.35 & -0.35 & -0.35 & 0.35 \\ 0.28 & -0.49 & 0.10 & 0.42 & -0.42 & -0.10 & 0.49 & -0.28 \\ 0.19 & -0.46 & 0.46 & -0.19 & -0.19 & 0.46 & -0.46 & 0.19 \\ 0.10 & -0.28 & 0.42 & -0.49 & 0.49 & -0.42 & 0.28 & -0.10 \end{pmatrix}.$$

Show how the number of multiplications and additions/subtractions required to perform the 8 point DCT can be reduced by exploiting the structure of the DCT matrix. Estimate the computational savings that could be achieved.

[12 marks]

(b) Describe how the DCT matrix can be used to calculate the 2D DCT of a grayscale image. How would the inverse DCT be applied?

[5 marks]

(c) Describe the ways in which the JPEG standard exploits the perceptual redundancy in the Human Visual System to colour and spatial contrast to improve the compression efficiency and perceived quality of compressed images.

[8 marks]