UNIVERSITY OF DUBLIN

TRINITY COLLEGE

FACULTY OF ENGINEERING, MATHEMATICS & SCIENCE

SCHOOL OF ENGINEERING

Electronic & Electrical Engineering

Senior Sophister
Engineering
Annual Examinations

Trinity Term, 2012

Digital Media Processing (4C8)

Date: 12th May 2012 **Venue: M17, MUSBLD** **Time: 14.00 – 16.00**

Dr. David Corrigan

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

All questions carry equal marks (or otherwise if the case)

Permitted Materials:

Calculator
Drawing Instruments
Mathematical Tables
Graph Paper

Section A - Compulsory Question

Q.1

(a) Sketch a block diagram of the stages in a lossy image compression and reconstruction system and clearly state the purpose of each block. For the compression stages state clearly how each block improves the coding efficiency of the compressor.

[7 marks]

(b) The Haar Transform is a well-known and simple technique for energy compaction. It is specified by a transformation matrix:

$$T = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

In the encoder, the transformed signal is quantised by rounding the coefficients in each Haar Transform band to the nearest integer multiple of the following quantisation step values:

$$Q = \begin{pmatrix} 2 & 4 \\ 4 & 4 \end{pmatrix}$$

If the top left 2x2 pixel block of an image has the intensities:

$$\begin{matrix} 20 & 11 \\ 19 & 13 \end{matrix}$$

(i) Use the matrix T to determine the Haar Transform coefficients for the image block and indicate the Haar Transform band that each coefficient belongs to.

[6 marks]

(ii) Determine the Haar coefficients after quantisation and hence determine the reconstructed image block.

[8 marks]

(iii) Calculate the mean squared error of the reconstructed image.

[4 marks]

Section B - Answer any 3 Questions

Q.2

(a) Using diagrams where necessary describe what is meant by the aperture effect in the context of block-based motion estimation. Describe the causes of the aperture effect and the types of image features that are associated with it. What type of image feature is not affected by the aperture effect?

[8 marks]

(b) The searching operation in a motion estimator that employs block matching, can be computationally intensive:

(i) For a full motion search, assuming that motion vectors are estimated to pixel accuracy, determine the number of operations (additions, subtractions and multiplications only) required to estimate the motion of a block. Clearly define any notation used.

[5 marks]

(ii) Describe how a multiresolution search can be used to improve the efficiency of block matching. To illustrate this use the example of a 3 level multi-resolution search to estimate motion when the desired search window size is 32 and the block size is 16 x 16. In your answer compare the total number of operations in the full motion search to that of the multiresolution search.

[12 marks]

Q.3

(a) The JPEG image compression standard stores images using a variant of the YUV colour-space known as YCbCr. Describe the transformation that converts an image from the RGB to YUV Colour space. **Note:** Exact values for the transformation are not required. Why is this colour-space favoured for use in JPEG?

[5 marks]

(b) An engineer implementing the JPEG compression standard wishes to assign suitable quantisation step sizes for each coefficient in the DCT of the luminance channel. After careful analysis the engineer arrives at the following quantisation step sizes:

$$Q = \begin{pmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{pmatrix}$$

(i) Explain how the engineer may have designed the experiment to arrive at these results.

[5 marks]

(ii) What do the measured values of the quantisation step sizes tell you about the response of the Human Visual System to spatial frequency?

[4 marks]

Continues Overleaf

Q.3 (Cont'd)

(c) In JPEG encoding separate Huffman Code tables are used for AC and DC coefficients. To encode the DC coefficients Differential Coding is used and a Huffman tree is built from these differential codes. To encode the remaining AC coefficients, the coefficients in each block are arranged in a Zig-Zag order and are encoded using a combination of Run Length Coding and Huffman Coding.

(i) What is Differential Coding and why is it used to encode the DC coefficients?
[3 marks]

(ii) What is meant by Run Length Coding? Why is it useful for JPEG compression?
[3 marks]

(iii) What is a Zig-Zag scan? Illustrate your answer by showing the Zig-Zag scan order for an 8x8 block of pixels. Why is a Zig-Zag scan preferred over a conventional reading order scan?
[5 marks]

Q.4

(a) Define what is meant by Perfect Reconstruction in the context of wavelet filter design. For a single-stage wavelet decomposition of a 1D Signal shown in Fig. Q.4, specify the relationship between the analysis and synthesis filters for Perfect Reconstruction to hold.

[5 marks]

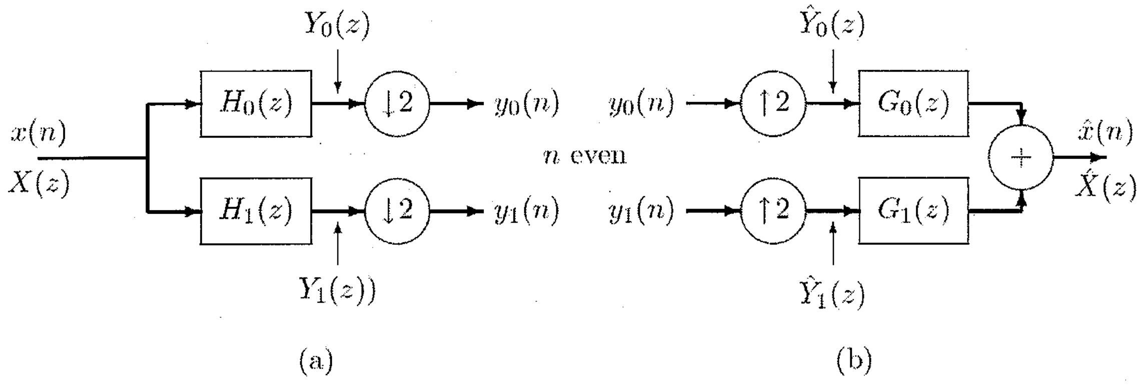

Fig. Q.4 Filter banks for analysis (a) and synthesis (b)

(b) Legall filters are to be used in a wavelet decomposition. These filters are described by:

$$H_0(z) = \frac{1}{2}\left(z + 2 + z^{-1}\right)$$

$$H_1(z) = \frac{1}{8}z^{-1}\left(-z^2 - 2z + 6 - 2z^{-1} - z^{-2}\right)$$

$$G_0(z) = \frac{1}{8}\left(-z^2 + 2z + 6 + 2z^{-1} - z^{-2}\right)$$

$$G_1(z) = \frac{1}{2}z\left(-z + 2 - z^{-1}\right)$$

Show that these filters meet the Perfect Reconstruction criteria.

[15 marks]

(c) Show how the 1D filter bank in Fig. Q.4 can be extended to create the filter bank for a 1 stage 2D Discrete Wavelet Transform. Clearly label the band corresponding to each output of the system.

[5 marks]

Q.5

(a) In 2-D filter design define what is meant by a separable filter and describe why such filters are advantageous. If a filter with a convolution mask of size N x M is to be applied to an image, how many multiplications and additions per pixel are required if the filter can be implemented separably and how many are required if it cannot.

[5 marks]

(b) Which of the following 2D filter masks are separable? For the separable filters, write down the corresponding vertical and horizontal filters.

(i) $\begin{matrix} 1 & 1 \\ 1 & -1 \end{matrix}$ **(ii)** $\begin{matrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{matrix}$ **(iii)** $\begin{matrix} 3 & 3 & 1 \\ 0 & 0 & 0 \\ 3 & 3 & 1 \end{matrix}$

[7 marks]

(c) The image shown in Fig. Q.5a has been filtered using three different 2D separable filters and the results are shown in Fig. Q.5b. The top-left, top-right and bottom-right images have been adjusted so that the mid grey intensity indicates a zero value with darker intensities representing negative values and lighter intensities representing positive intensities.

Each of the separable filters was constructed by using a combination of two from a set of four filters which have the following convolution masks.

$$\begin{pmatrix} 1 & 1 \end{pmatrix} \qquad \begin{pmatrix} -1 & 1 \end{pmatrix} \qquad \begin{pmatrix} -1 \\ 1 \end{pmatrix} \qquad \begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

Considering carefully the filtering action on each of the images in Fig. Q.5b, identify the filters used on each image and determine the corresponding 2D convolution mask.

[13 marks]

Fig. Q.5a - A Greyscale Image

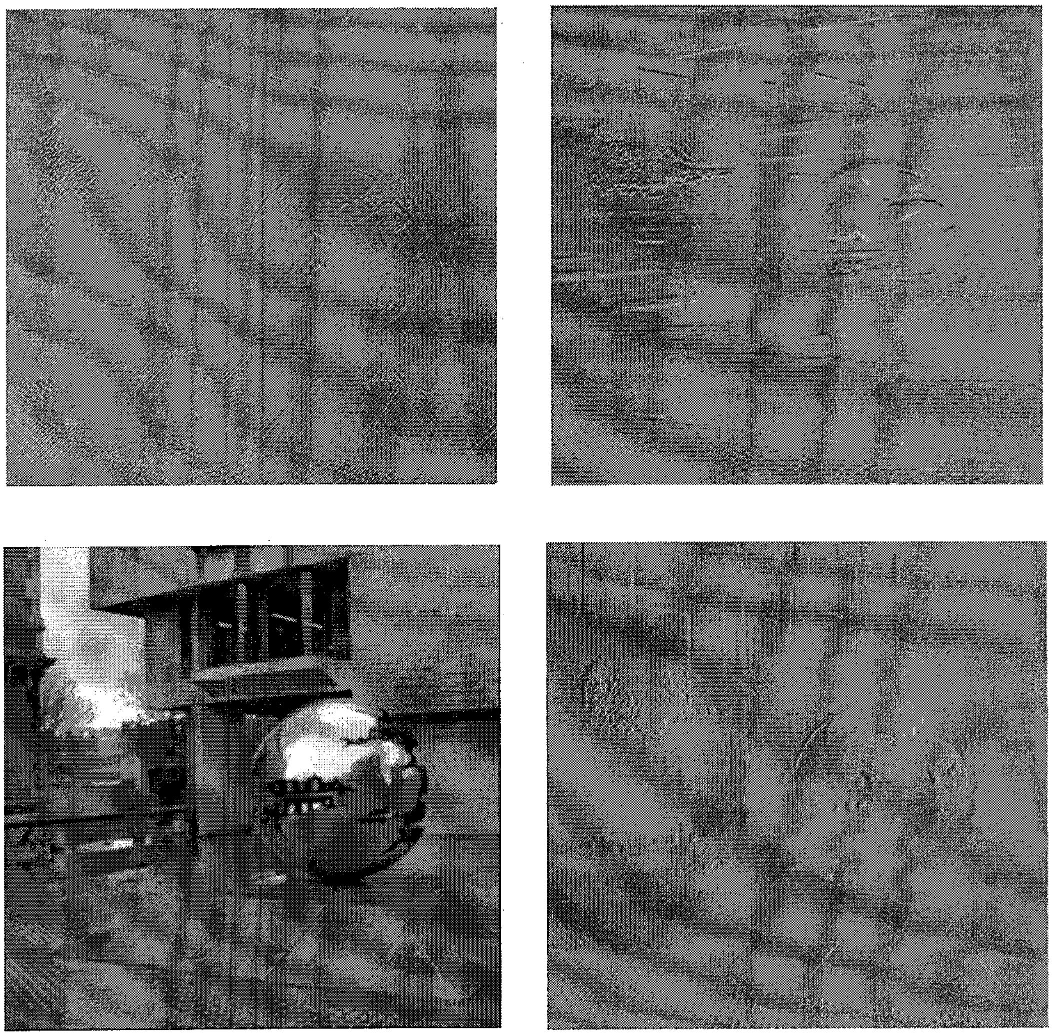

Fig. Q.5b - Results of four different separable filter operations on the image in Fig. Q.5a.