XEE4C081

UNIVERSITY OF DUBLIN

TRINITY COLLEGE

FACULTY OF ENGINEERING, MATHEMATICS & SCIENCE

SCHOOL OF ENGINEERING

Electronic and Electrical Engineering

Senior Sophister Engineering **Trinity Term, 2011**

Annual Examinations

DIGITAL MEDIA PROCESSING (4C8)

Date: 17th May 2011 **Venue: Sports Centre** **Time: 14:00-16:00**

Prof. A. C. Kokaram

Answer question 1 and any THREE (3) of the remaining FOUR (4) questions. Please answer questions from each section in separate answer books.

Permitted Materials:

- **Calculator**
- **Drawing Instruments**
- **Mathematical Tables**
- **Graph Paper**

SECTION A: COMPULSORY

Q1. **(a)** Figure Q1.1 shows the frequency spectrum of an analogue signal $f(x,y)$ with bandwidth $(\Omega_1,\ \Omega_2)$ rad/m. That signal is sampled at a rate $(3\Omega_1, 3\Omega_2)$ in both directions. Sketch the frequency spectrum of the sampled signal in the ranges $(-4\Omega_1 < \omega_1 < 4\Omega_1)$ and $(-4\Omega_2 < \omega_2 < 4\Omega_2)$ respectively. **[10 marks]**

(b) Figure Q1.2(a) shows an image $f[h,k]$ that was created by sampling $f(x,y)$ at a rate of (D_x, D_y) samples per metre in both directions. Figure Q1.2(b) shows $f(x,y)$ sampled at a rate $(D_x/6, D_y/6)$ but displayed in the same area as Figure Q1.2(a). Describe the artefacts present in this new image and explain why they occur. You should reference the answer you gave to part (a) of this question in making your explanation. **[10 marks]**

(c) In an attempt to remove the artefacts present in Figure Q1.2(b), $f(x,y)$ is filtered with a low pass filter $H(\omega_1, \omega_2)$ before being sampled at a rate of $(D_x/6, D_y/6)$. Two options are tested for that filter : $H_1(\omega_1, \omega_2)$ and $H_2(\omega_1, \omega_2)$. The first is an ideal low pass filter with a bandwidth of $(\Omega_1/12, \Omega_2/12)$ rad/m , and the second is a Gaussian filter with a 3dB bandwidth that is $(\Omega_1/20, \Omega_2/20)$ rad/m. Figures Q1.2(c), Figures Q1.2(d) show the resulting output images after sampling in no particular order. Match the filters to the corresponding output explaining your choice in terms of the visual appearance of the sampled image.

[5 marks]

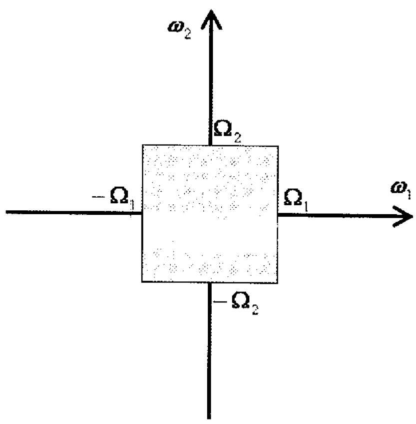


Figure Q1.1: *Spectrum of* $f(x,y)$.

a) b) c) d)

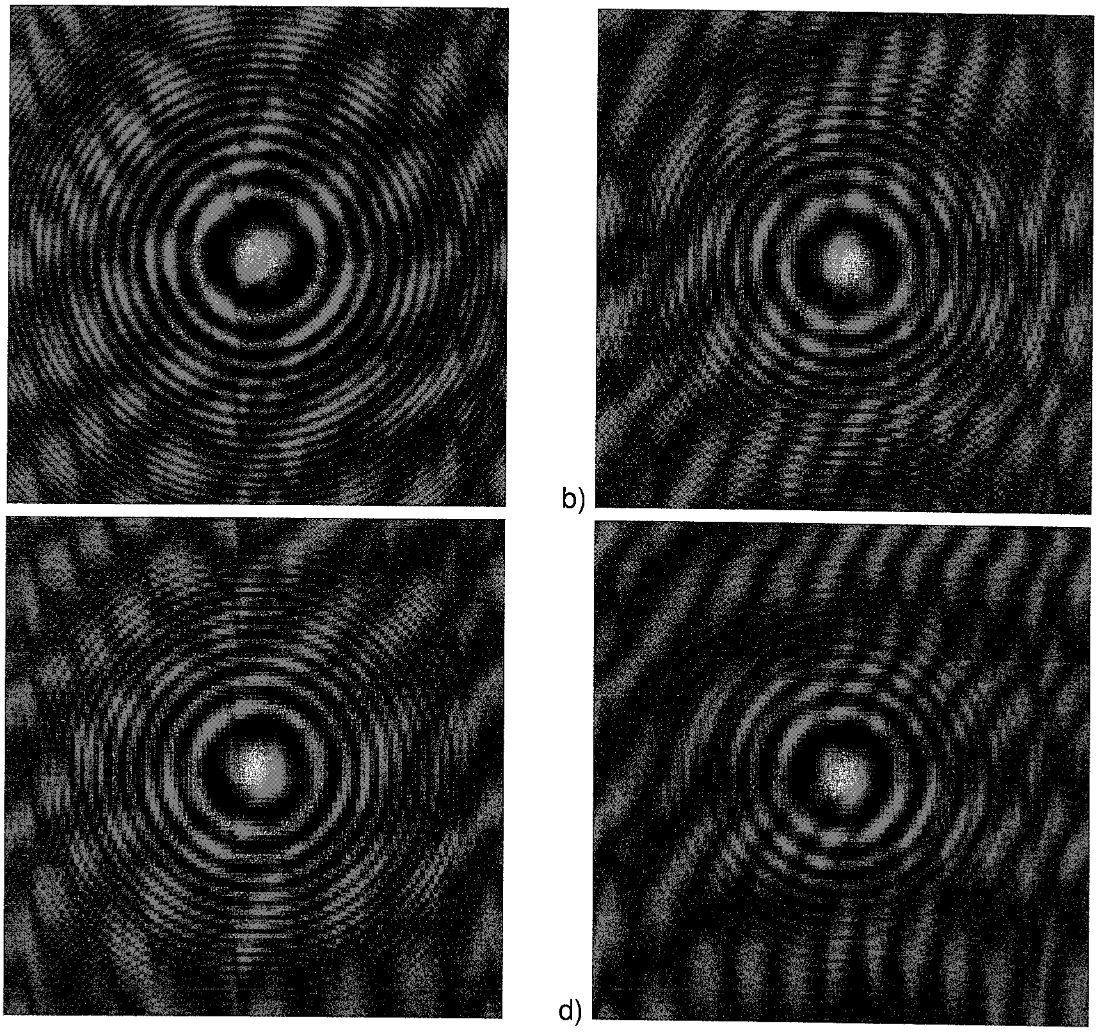


Figure Q1.2: *Different filtered and downsampled versions of the zoneplate image*

SECTION B

Q2. Figure Q2.1 (below) shows the filter structure used in the analysis and reconstruction units of a 1D Perfect Reconstruction filterbank.

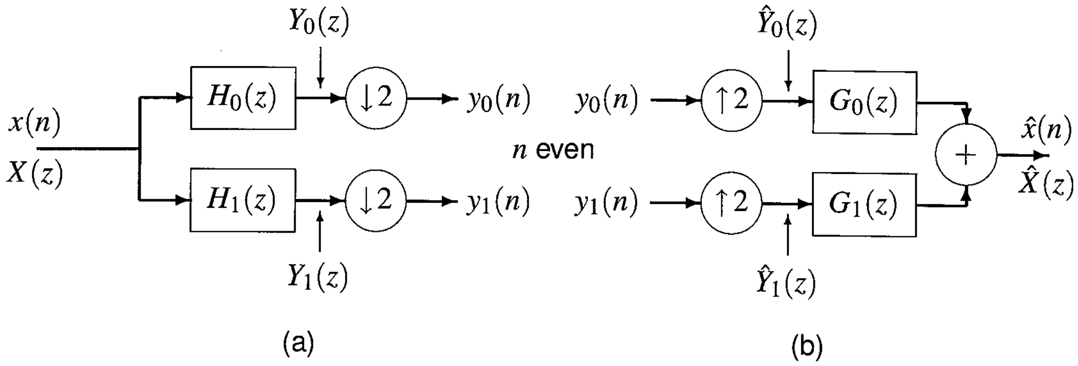


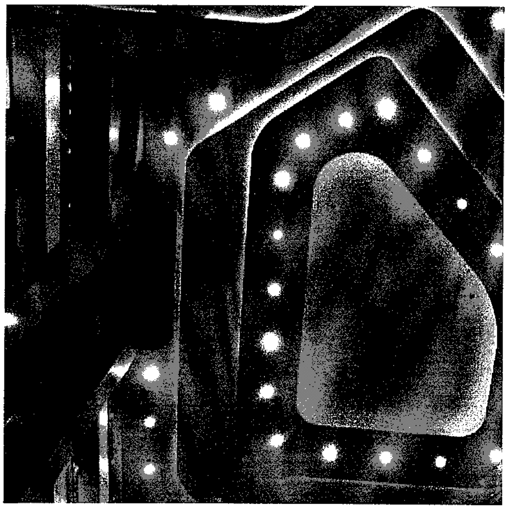
Figure Q2.1: *Two-band filter banks for analysis (a) and reconstruction (b).*

(a) Draw a block diagram showing how the analysis stage above can be applied to create a 2D analysis filter bank resulting in 2 levels of decomposition. **[12 marks]**

(b) Figure Q2.2 shows a single grey scale image. Figure Q2.3 shows a series of bandpass images which correspond to the 2D DWT of the image to the left of Figure Q2.2 using the Haar wavelet at level 1. The brightness of the images has been adjusted for easier viewing and the mid-gray scale level corresponds to a value of 0 (zero). Identify the corresponding Lo-Lo, Hi-Lo, Lo-Hi and Hi-Hi sub-bands at Level 1 of the 2D DWT from the bandpass image set shown in Figure Q2.3. Use the typical convention shown for arrangement of 2D DWT sub-bands as indicated in Figure Q2.2. Explain your selections.

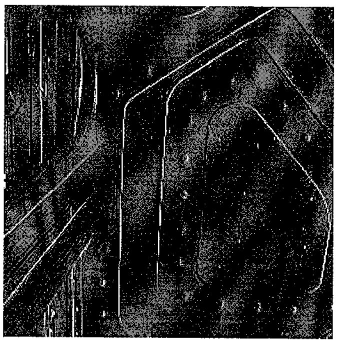
[8 marks]

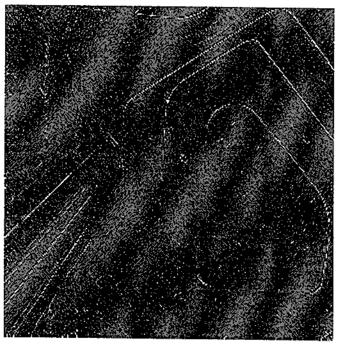
(c) Assuming that the values of a signal are distributed according to a Laplacian distribution, the Entropy H can be approximated with $H = \log_2\left(\frac{2ex_0}{Q}\right)$ where Q is the quantiser step size, e is a constant and x_0 is the mean absolute value of the signal. The image in Figure Q2.2 is to be compressed using the Haar Wavelet transform. By observing the corresponding DWT images and assuming a constant Q, state whether the entropy in the bandpass images are lower or higher than the original image and explain why. Hence state why the transform stage achieves image compression. **[5 marks]**

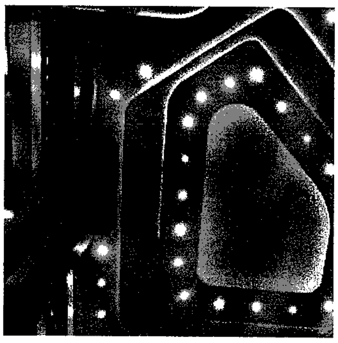


Lo-Lo	Hi-Lo
Lo-Hi	Hi-Hi

Figure Q2.2: *Left : A Grey Scale Image. Right : The convention used for ordering the Level 1 sub-bands of the 2D DWT*

1) 

2) 

3) 

4) 

Figure Q2.3: *Level 1 Subbands of the 2D DWT using the Haar Transform.*

Q3. **(a)** A Full Search Block Matcher (FSBM), with integer accuracy, is to be used for estimating motion in a sequence of images. A block size of $B \times B$ pixels ($B = 8$), and a search width of $w = \pm 4$ pixels are used. Estimate the total number of operations (C_2) required to perform the motion estimation on every block of pixels in an entire 1920×1080 HD frame.

[10 marks]

(b) A pixel based motion detector is used to detect motion in a real video signal, $G_n(\mathbf{x})$, before FSBM. It measures the absolute value of pixel difference $\Delta_n(\mathbf{x})$, at a site $\mathbf{x}$, and assumes motion when $|\Delta_n(\mathbf{x})| > T_\Delta$, where T_Δ is some threshold.

Assume that the probability distribution of the pixel difference $\Delta_n(\mathbf{x})$ is Laplacian with $x_0 = 6.5$ as follows.

$$p(\Delta_n(\mathbf{x})) = \frac{1}{2x_0} \exp\left(\frac{-|\Delta_n(\mathbf{x})|}{x_0}\right) \tag{1}$$

i. Show that the probability that a pixel is detected as moving is $p_m(T_\Delta) = \exp(-T_\Delta / x_0)$.

[5 marks]

ii. A block based motion detector is built using this pixel based detector, with $T_\Delta = 1$, by detecting motion in a block when more than 50 % of the pixels in a block have been flagged as moving by the pixel based motion detector. Given a block size of 8×8 pixels, calculate the probability that a block is detected as moving. **[5 marks]**

iii. Hence or otherwise estimate the computational savings C_1/C_2 created by the motion detector, where C_1 is the number of operations required to perform FSBM (with the parameters used in this example) after motion detection on a frame of size 1920×1080, and C_2 is as defined above. Note that your estimate of C_1 should also include the operation count for implementing the motion detection stage. **[5 marks]**

Q4. **(a)** The DCT coefficient matrix for transforming a single 8 pixel row into 8 coefficients of the DCT is shown below. Show how the number of multiply/add operations required to perform the 8 point DCT can be reduced by exploiting the structure in the matrix below. Estimate the reduction in operation count that you achieve. **[10 marks]**

$$\begin{bmatrix} 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 & 0.3536 \\ 0.4904 & 0.4157 & 0.2778 & 0.0975 & -0.0975 & -0.2778 & -0.4157 & -0.4904 \\ 0.4619 & 0.1913 & -0.1913 & -0.4619 & -0.4619 & -0.1913 & 0.1913 & 0.4619 \\ 0.4157 & -0.0975 & -0.4904 & -0.2778 & 0.2778 & 0.4904 & 0.0975 & -0.4157 \\ 0.3536 & -0.3536 & -0.3536 & 0.3536 & 0.3536 & -0.3536 & -0.3536 & 0.3536 \\ 0.2778 & -0.4904 & 0.0975 & 0.4157 & -0.4157 & -0.0975 & 0.4904 & -0.2778 \\ 0.1913 & -0.4619 & 0.4619 & -0.1913 & -0.1913 & 0.4619 & -0.4619 & 0.1913 \\ 0.0975 & -0.2778 & 0.4157 & -0.4904 & 0.4904 & -0.4157 & 0.2778 & -0.0975 \end{bmatrix}$$

(b) What are the functions of the *Quantisation* and *Entropy Coding* stages in an Image Compression system? **[10 marks]**

(c) Briefly explain why a zigzag scan of the DCT coefficients calculated during JPEG compression is preferred over a raster scan. **[5 marks]**

Q5. One key factor affecting the performance of each different flavour of MPEG compression is the error-resilience of the scheme.

(a) When an error occurs in a bitstream it can cause subsequent data to be decoded erroneously. What is the reason for this effect in MPEG2 and what is the main corrective strategy used in that standard? **[10 marks]**

(b) Consider an MPEG2 video stream received in a digital set top box with a GOP structure of $IBBPBBPBBP$. The set top box is damaged and all the B frames become corrupted. This box has no smart error correction in the decoder, although it is smart enough to skip to the next start-of-frame in the stream. The corruption is such that the data associated with each P frame is fine. Explain what the viewer might observe on his TV set. **[5 marks]**

(c) A viewer has just bought a very expensive HDTV and is watching rugby. The viewer calls in to technical support to complain that whenever the camera moves, the pitch seems to "`go all glassy`", but when it stops the grass is "`all fine again`". He asks if something is wrong with his settop box. Would your advice be to bring in the set for repair or not? Explain your answer. **[10 marks]**