UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2005/2006

November 2005

EEE 512 – ADVANCED DIGITAL SIGNAL AND IMAGE PROCESSING

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **NINE (9)** printed pages and **SIX (6)** questions before answering.

Answer **FIVE (5)** questions.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

...2/-

1. (a) The following transfer function represents a filter

$$H(z) = \sum_{k=0}^{11} h(k) z^{-k}$$

Where

h(n) = h(11-n) for n=0,1,2,3,4,5

(i) State the type of the filter

(ii) Write down the difference equation of the filter.

(iii) Draw the filter structure that requires minimum computations.

(30%)

(b) The block diagram of a three stage decimator that is used to reduce the sampling rate from 3072 kHz to 48 kHz is as shown in Figure 1. Assuming decimation factors of 8, 4, 2, indicate the sampling rate at the output of each of the three stages.

(30%)

(c) If the decimator in part (b) above satisfies the following over-all specifications

Input sampling frequency F_s	= 3072 kHz
Decimation Factor M	= 64
Pass-band ripple	= 0.01 dB
Stop-band ripple	= 60 dB
Frequency band of interest	= 0 – 20 kHz

...3/-

Determine the band-edge frequencies for the decimating filter at each stage. The band stop frequency for the ith stage is given by the relation

$$f_{si} = F_i - (F_s/2M)$$

Where F_i = Output sampling rate for the ith stage
F_s = The system basic sampling rate
f_{si} = Stop-band edge frequency for the ith stage.

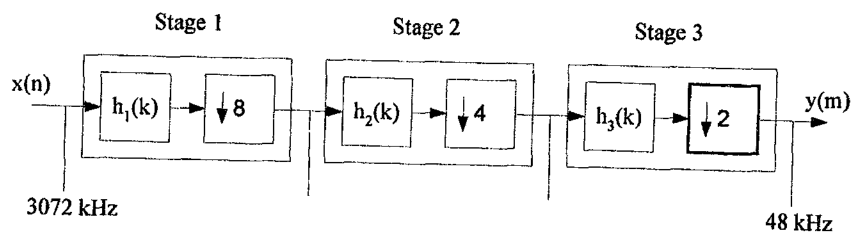

Figure 1

(40%)

2. (a) A digital filter is required for real time physiological noise reduction. The filter should meet the following amplitude response specifications

Pass band	0 – 10 Hz
Stop band	20 – 64 Hz
Sampling frequency	128 Hz
Maximum passband deviation	< 0.036 dB
Stopband attenuation	> 30 dB

Other important requirements are that

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(i) Minimal distortion of the in-band components.

(ii) The time available for filtering is limited, the filter being part of a larger process.

Discuss the five main steps involved in the design of such a filter. Also discuss the type and structure of the filter that is most appropriate under the given conditions.

(40%)

(b) A simple IIR notch filter has the following normalized s-plane transfer function

$$H(s) = \frac{s^2 + 1}{s^2 + s + 1}$$

Determine the transfer function of an equivalent digital filter using the BZT method. Assume a notch frequency of 50 Hz and a sampling rate of 500Hz. The direct low-pass to low-pass frequency scaling is given by

$$s = \frac{s}{\omega'_p}$$

where the symbols have their usual meanings.

(60%)

...5/-

3. (a) A linear phase band-pass filter is to be designed using the optimal method. The filter should have the following specifications

Passband	900 – 1100 Hz
Pass band ripple	< 0.87 dB
Stopband attenuation	> 30dB
Sampling frequency	15 kHz
Transition band	450 Hz

Determine the normalized band edge frequencies for the filter and choose suitable weights for the bands.

(40%)

(b) Show stating any assumptions, that the maximum stop-band attenuation possible, A_{max}, for a direct form low pass FIR filter, with coefficients quantized by rounding, is bounded by

$$A_{max} \leq 20 \log_{10} (2^{-B}N)$$

Where B is the coefficient word length (two's complement representation) and N is the order of the filter.

(60%)

4. (a) The gray scale distribution of an image $f(x, y)$ of size 64 x 64 pixels quantized over 8 levels, i.e. r_k ; k = 0, 1, 2, 3, 4, 5, 6, 7 is tabulated in Table 4(a).

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Table 4(a)

r_k	n_k
0	112
1	266
2	545
3	789
4	1125
5	645
6	550
7	64

Using Table 4(a) or otherwise, show that a second pass of histogram equalization will produce exactly the same result as the first pass. Hence, explain why discrete histogram equalization does not, in general, yield a flat histogram.

(40%)

(b) The histogram of an image of gray level r has been approximated by the probability density function.

$$P_r(r) = Ae^{-r} \;;\quad 0 \le r \le b$$

Calculate the transformation function $S = T(r)$, where S is the gray value in the transformed image, such that the transformed image has the probability density function.

$$P_z(z) = Bze^{-z^2} \quad;\quad 0 \le z \le b$$

where A and B are normalizing factors.

(60%)

5. (a) Consider the image given in Figure 5(a). Show the resulting images (magnitude and direction images where applicable) if the following edge detectors are used:

(i) Laplacian operator in 4-neighborhood

(ii) Sobel operator

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 10 & 10 & 0 & 0 & 0 \\ 0 & 0 & 10 & 10 & 10 & 10 & 0 & 0 \\ 0 & 0 & 0 & 10 & 10 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 5(a)

(40%)

...8/-

(b) A 2-D filter function in the spatial domain is given by:

$$g(x, y) = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

(i) Derive the filter function *H (u, v)* for performing the equivalent process in the frequency domain.

(40%)

(ii) Show that *H(u, v)* is a low-pass filter. (20%)

Given

$$\Im f(x - x_0, y - y_0) = F(u,v)\; e^{-j2\pi\left(\frac{ux_0}{M} + \frac{vy_0}{N}\right)}$$

$$2 \cos x = e^{jx} + e^{-jx}$$

6. (a) Let A denote the set shown in Figure 6(a). Refer to the structuring elements shown (the black dots denote the origin), sketch the result of the following morphological operations:

(i) $(A \ominus B^4) \oplus B^2$

(ii) $(A \ominus B^1) \oplus B^3$

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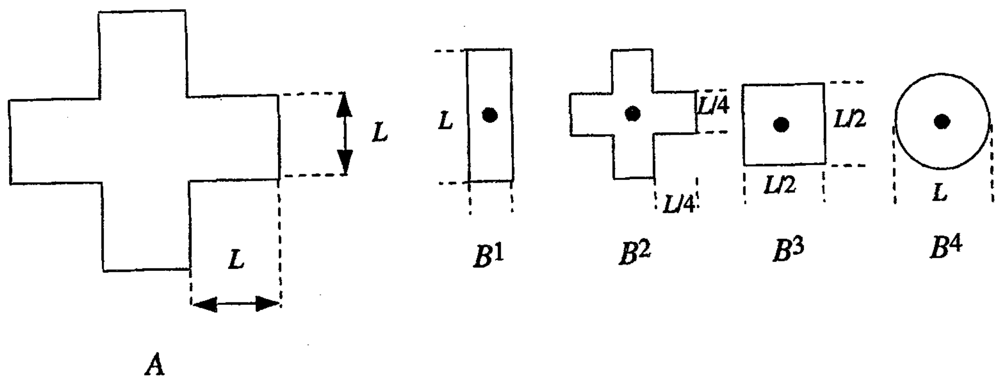

Figure 6(a)

(40%)

(b) Study Figures 6 which show (a) 8 x 8 binary image A, and (b) 3 x 3 structuring element B.

$$A = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

(a) (b)

Figure 6

(i) Determine the skeleton of *A*. (30%)

(ii) Reconstruct *A* from its skeleton. (30%)

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