UNIVERSITI SAINS MALAYSIA

First Semester Examination

Academic Session 2003/2004

September/October 2003

EEE 502 – ADVANCED DIGITAL SIGNAL AND IMAGE PROCESSING

Time : 3 Hours

INSTRUCTION TO CANDIDATES:-

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

Answer **FIVE (5)** questions.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

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Assume with justification any data required

1. (a) Find the magnitude and phase response for the system characterized by the difference equation

$$y(n) = \frac{1}{6}x(n) + \frac{1}{3}x(n-1) + x(n-2).$$

Hence show that the equation represents a linear phase digital FIR filter.

(50 marks)

(b) An anti-aliasing filter has a transfer function given by

$$H(z) = \frac{1-4z^{-1}}{1+5z^{-1}}.$$

Obtain the poly-phase decomposition of the filter if the decimation factor has a value equal to 2.

(50 marks)

2. (a) Show that the Bilinear Transformation maps the points in the left-half of the s-plane into points inside the unit circle in the z-plane and the transformation results in a stable digital system.

(50 marks)

(b) Prove the identity shown in Figure 1.

(50 marks)

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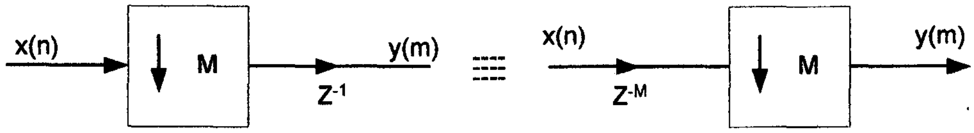

Figure 1

3. (a) A linear Shift-invariant system has a unit sample response given by

$$h(0) = -0.01,\ h(1) = 0.02,\ h(2) = -0.10,\ h(3) = 0.40,\ h(5) = 0.02,\ h(6) = -0.01.$$

[i] Draw a signal flow graph for this filter that requires the minimum number of multiplications.

[ii] In order to avid overflow, each node of the network is constrained to be a fraction less than unity in magnitude. Determine the maximum value the output can attain.

(50 marks)

(b) An analog signal is to be filtered with an analog low-pass filter that has a cut-off frequency f_c =2 kHz with Δf = 500 Hz and a stop band attenuation of 50 dB. This filter is to be implemented digitally. Obtain the impulse response of the digital filter to meet the analog filter specifications with a sampling frequency f_s = 10 kHz.

(50 marks)

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4. (a) Discuss the limiting effect of repeatedly applying the histogram equalisation to a digital image.

(40 marks)

(b) The gray scale distribution n_k of an image $f(x, y)$ of size 64×64 pixels quantised over 8 levels, i.e r_k ; $k = 0,1,2,3,4,5,6,7$ is tabulated in Table 4(b1) whereas Table 4(b2) shows the specified histogram with probability density function P_z.

r_k	n_k
0	612
1	163
2	335
3	573
4	1186
5	613
6	614
7	0

Table 4(b1)

z_k	$p_z(z_k)$
0	0
1	0.05
2	0.1
3	0.2
4	0.3
5	0.2
6	0.1
7	0.05

Table 4(b2)

(i) Perform histogram equalisation on $f(x, y)$ and tabulate the gray scale distribution which maps $r_k \rightarrow s_k$.

(20 marks)

(ii) From (i) show that a second pass of histogram equalisation will produce exactly the same result.

(20 marks)

(iii) Perform histogram equalisation using specified probability density function shown in Table 4(b2). Tabulate the new gray scale value as a function of r_k.

(20 marks)

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5. Digital operation such as the XNOR is often used in industrial applications for detecting missing components in product assembly. The approach is to store a "golden" image that corresponds to a correct assembly; this image is then XNORed from incoming images of the same product. Ideally, the number of matches is maximum if the new products are assembled correctly. XNORed images for products with missing components would contain many zero entries indicating the level of mismatches. Briefly, describe what conditions that have to be met in practice for this method to work.

(100 marks)

6. (a) Using a suitable example, explain the simple use of image dilation and erosion.

(40 marks)

6. (b) Study the following 11×11 and 3×3 matrices:

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

where A denotes a binary image and B denotes the structuring element. Using A and B:

(i) determine the last iterative step K such that:

$$K = \max\{k \mid (A \oplus kB) = \emptyset\}$$

(20 marks)

(ii) from 6b(i), determine the skeleton of A,

(20 marks)

(iii) from 6b(ii), reconstruct A.

(20 marks)

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