UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2006/2007

October/November 2006

EEE 512 – ADVANCED DIGITAL SIGNAL AND IMAGE PROCESSING

Duration: 3 hours

Please check that this examination paper consists of SEVEN pages of printed material and ONE page Appendix before you begin the examination.

This paper contains SIX questions.

Instructions: Answer **FIVE (5)** questions. If a candidate answer more than five questions, only the first five answered will be examined and awarded marks.

Answer to any question must start on a new page.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

1. (a) Explain the difference between image enhancement and image restoration.

(20%)

(b) Given the original image as shown in Figure 1, find the resulting magnitude and orientation images for Sobel edge detector. Ignore the border pixel.

(40%)

0	0	0	0	0	0
0	0	2	0	2	4
0	2	2	0	2	4
0	0	2	0	2	0
0	0	2	0	2	4
0	0	0	0	2	4

Figure 1

(c) Design a morphological operation with the necessary structuring element that can locate the isolated point in the following image.

(40%)

0	0	0	0	0	0	0	0
0	1	0	0	0	1	1	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0

2. (a) Briefly explain a technique to remove the impulse noise on image?

(20%)

(b) Given the histogram below of an image, 16 rows by 16 columns and with only 8 grey-level values:

Grey-level	0	1	2	3	4	5	6	7
No. of pixels	7	26	29	96	38	47	7	6

Implement the process of histogram equalization and show the new histogram.

(30%)

(c) Given the following image

0	0	1	1
1	1	0	0
0	0	1	1
1	1	0	0

And the Haar function are defined as

$$H_0(t) = \frac{1}{\sqrt{N}}; \text{ for } t \in [0,1]$$

$$H_k(t) = \frac{1}{\sqrt{N}} \begin{cases} 2^{p/2}; & \frac{q-1}{2^p} \le t < \frac{q-\frac{1}{2}}{2^p} \\ -2^{p/2}; & \frac{q-1}{2^p} \le t < \frac{q-\frac{1}{2}}{2^p} \\ 0 & ; \text{ otherwise for } t \in [0,1] \end{cases}$$

$k = 2^p + q - 1$

$N = 2^J;$

$0 < p \le J - 1$

(i) Construct the Haar matrix with N=4 (10%)

(ii) Perform the Haar transform on the given image. (10%)

(iii) Perform the inverse Haar transform using only the first three rows of the coefficients.

(15%)

(iv) Calculate the mean square error of the reconstruction. (15%)

3. (a) Using the Hamming window obtain the total number of coefficients and the values of the first three {h(0), h(1), h(2)} coefficients of an FIR low-pass digital filter to meet the specifications given below. Ignore all smearing effects.

Pass-band edge frequency:	1.5 kHz
Transition width:	0.5 kHz
Stop-band attenuation:	> 50dB
Sampling frequency:	8 kHz

(50%)

(b) The following transfer function represents an IIR filter

$$H(z) = \frac{b_0 + b_1 z^{-1} + b_2 z^{-1}}{1 + a_1 z^{-1} + a_2 z^{-1}}$$

(i) Represent the filtering operation in a block diagram form and write the difference equation.

(15%)

(ii) Determine and comment on the computational and storage requirements.

(15%)

(c) A computer program based on the optimal method will be used to design a notch filter that is required to satisfy the following specifications.

Notch frequency: 1.875 Hz
Attenuation at notch frequency: >60dB
Pass-band edge frequencies: 1.575 and 2.175 kHz
Pass-band ripple: <0.01 dB
Sampling frequency: 7.5 kHz
Number of filter coefficients: 61

Determine the normalized frequencies and the weights that are needed as inputs to the computer program.

(20%)

4. (a) It is required to monitor the electrical activity (ECG) of a baby's heart while still in the mother's womb. Because of the existence of signal energy in the neighborhood of the mains frequency (50 Hz), it is necessary to use a very narrow band filter. The specifications of the filter are

Pass-band: 49 – 51 Hz
Stop-band edge frequencies: 47 and 53 Hz
Stop-band attenuation: 30 dB
Pass-band ripple: 0.1 dB
Sampling frequency: 500Hz

If designed directly the above filter requires 4018 coefficients, which is too long. The option is therefore, to decimate the data to as low rate as possible. Keeping in view the above, write down the overall specifications of a suitable decimator and also mention the number of stages.

(60%)

(b) The normalized transfer function of an analog R-C filter is given by

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

Starting from the s-plane equation, determine using the BZT method, the transfer function of an equivalent digital high-pass filter. Assume a sampling frequency of 150 Hz and cut-off frequency of 30 Hz.

(40%)

5. (a) A low pass FIR filter has the following specifications

Pass-band deviation: 0.05 dB
Sampling frequency: 10 kHz
Pass-band edge frequency: 1.8 kHz
Transition width: 500 Hz
Number of coefficients: 65

If 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 number of bits used to represent each filter coefficient and N is the filter length.

(i) Estimate the number of bits required to represent each coefficient for the filter to have an attenuation of at least 60 dB in the stop band.

(30%)

(ii) If the coefficient word length in (i) is used, estimate the expected increase in pass-band ripple and the reduction in stop-band attenuation in decibels.

(30%)

(b) Explain what you understand by aliasing. A signal x(t) is given by

$$x(t) = 5\cos 2\pi 100t + 3\cos 2\pi 500t.$$

It is required to sample x(t) at twice the Nyquist rate. Write down giving reasons suitable specifications of an anti-aliasing filter.

(40%)

6. (a) A discrete signal s(n) is corrupted by additive random noise d(n) resulting in the noisy signal (n) = s(n) + d(n). A two point causal moving average filter is to be designed that will operate on x(n) to give an output y(n) that is a reasonable approximation to s(n). Determine the impulse response and transfer function of such a filter.

(60%)

(b) Mathematically derive the conditions necessary for a realizable digital filter to have a linear phase characteristic. Discuss the advantages of filters with such a characteristic.

(40%)

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List of Formulae

- For the Hamming window:

  Normalized transition width = 3.3/ N.

  Pass-band ripple (dB) = 0.0194.

  Main-lobe relative to side-lobe (dB) = 41.

  Stop-band attenuation maximum (dB) = 53.

  Window function: $w(n) = 0.54 + 0.46 \cos(2\pi n/N)$, $|n| \leq (N-1)/2$.

  N is the number of filter coefficients.

- The pre-warped analog frequency ω' is related to the digital domain frequency ω by the relation $\omega' = \tan(\omega T/2)$, T being the sampling period.

- For low-pass to high-pass transformation $s = \omega_p'/s$

- For BZT $H(z) = H(s)$ for $s=(z-1)/(z+1)$