UNIVERSITI SAINS MALAYSIA

Second Semester Examination

Academic Session 2004/2005

March 2005

EEE 502 – ADVANCED DIGITAL SIGNAL AND IMAGE PROCESSING

Time : 3 Hours

INSTRUCTION TO CANDIDATE:-

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.

Note: Use SI system of units
Assume suitable data with justification where necessary

1. (a) A band-pass filter is required to satisfy the following specifications: (70%)

$$0.98 \le |H(e^{j\omega})| \le 1.02 \qquad 0 \le \omega \le 0.2\pi$$
$$|H(e^{j\omega})| \le 0.001 \qquad 0.22\pi \le \omega \le 0.78\pi$$
$$0.95 \le |H(e^{j\omega})| \le 1.05 \qquad 0.8\pi \le \omega \le \pi$$

[i] Estimate the order of the equiripple filter required to meet the specifications if the order of such a filter is given by

$$N = \frac{-10\log(\delta_p \delta_s) - 13}{14.6\Delta f}$$

Where δ_p and δ_s are the passband and stopband ripples, respectively, and Δf is the transition width.

[ii] What weighting function should be used to design this filter?

[iii] What is the minimum number of extremal frequencies the filter must have?

(b) Given $x(n) = 2^n$ and N= 8, find X(k) using DIT FFT (30%)

2. (a) Obtain the polyphase decomposition of the IIR filter with transfer function (50%)

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

(b) The unit sample response of an FIR filter is (50%)

$$h(n) = \begin{cases} \alpha^n & 0 \le n \le 6 \\ 0 & \text{otherwise} \end{cases}$$

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[i] Draw the direct form implementation of this system.

[ii] Show that the corresponding system function is

$$H(z) = \frac{1-\alpha^7 z^{-7}}{1-\alpha z^{-1}} \qquad |z| > 0$$

and use this to draw a flow graph that is a cascade of an FIR system with an IIR system.

[iii] For both of the implementations in b[ii] above determine the number of multiplications and additions required to compute the output value and the number of storage registers required.

3. (a) Use the bilinear transformation to design a digital low pass filter that has a 3-dB cutoff frequency $\omega_c = 0.2\pi$, using a first order low-pass Butterworth filter.

(50%)

(b) A second order filter is described by the following difference equation

(50%)

$$y(n) - y(n-1) + \frac{3}{16} y(n-2) = x(n) - \frac{1}{2} x(n-1)$$

Find-

[i] The impulse response of the filter

[ii] The frequency response of the filter

[iii] The magnitude response of the filter

[iv] The phase response of the filter

4. (a) Suppose that a digital image is subjected to histogram equalisation. Show that a second pass of histogram equalisation will produce exactly the same result as the first pass.

(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 4b(i) whereas Table 4b(ii) shows the specified histogram with probability density function p_z.

r_k	n_k
0	346
1	785
2	1532
3	842
4	225
5	150
6	145
7	71

Table 4b(i)

z_k	$p_z(z_k)$
0	0.01
1	0.02
2	0.15
3	0.23
4	0.31
5	0.21
6	0.04
7	0.03

Table 4b(ii)

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

(20 marks)

(ii) Perform second round of histogram equalisation on $f(x, y)$ and comment your result.

(20 marks)

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

(20 marks)

5. (a) A spatial filter that averages the four immediate neighbours of a point (x, y) but excludes itself. Find the equivalent filter $H(u, v)$ in the frequency domain. Hence, show that your result is a lowpass filter.

(40 marks)

(b) The two Fourier spectra shown are of the same image. The spectrum in Fig. 5b(i) corresponds to the original image, and the spectrum in Fig. 5b(ii) was obtained after the image was padded with 255s for 8 bit system.

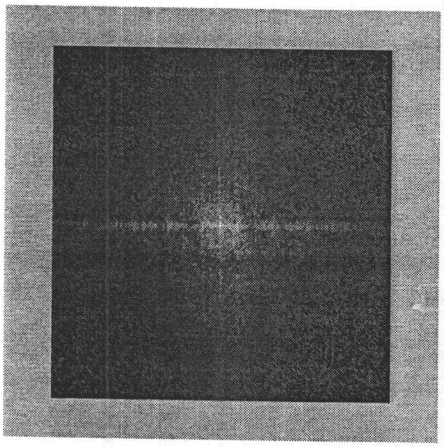

Fig. 5b(i)

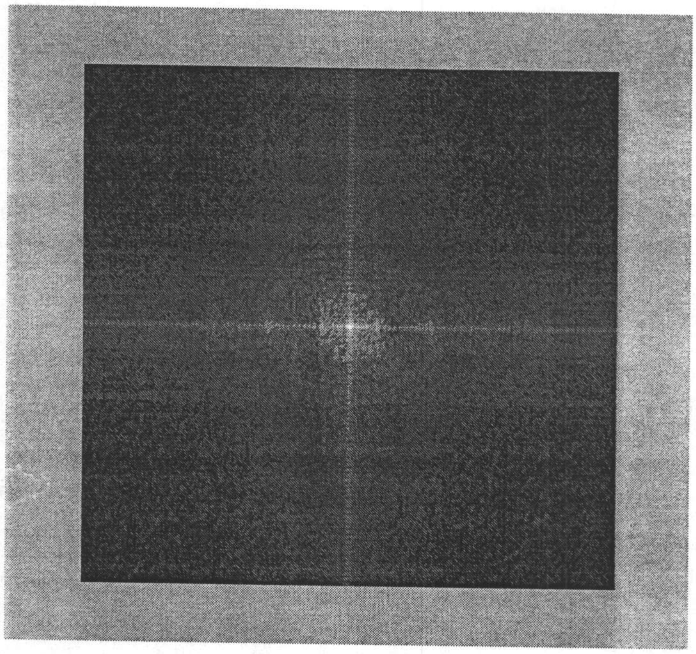

Fig. 5b(ii)

(i) Explain the difference in the overall contrast

(20 marks)

(ii) Using diagram but without detailed mathematical derivation, explain the significant increase in signal strength along the vertical and horizontal axes of the spectrum shown in Fig. 5b(ii).

(40 marks)

Given:

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

6. (a) A certain x-ray imaging geometry produces a blurring degradation that can be modeled as the convolution of the sensed image with the spatial, circularly symmetric function

$$h(r)=[(r^2-\sigma^2)/\sigma^4]e^{-r^2/2\sigma^2}$$

where $r^2=x^2+y^2$. Show that the degradation in the frequency domain is given by the expression

$$H(u,v)=-\sqrt{2\pi}\sigma(u^2+v^2)e^{-2\pi^2\sigma^2(u^2+v^2)}$$

(50 marks)

(b) From 6(a) or otherwise, give the expression for a Wiener filter, assuming that the ratio of power spectra of the noise and undegraded signal is constant.

(50 marks)

Given:

$$\Im[\nabla^2 f(x,y)]=-(u^2+v^2)F(u,v)$$

$$\Im\left[e^{-(x^2+y^2)/2\sigma^2}\right]=\sqrt{2\pi}\sigma e^{-2\pi^2\sigma^2(x^2+y^2)}$$

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