EE E4830 Digital Image Processing, Spring 2004

Midterm Exam
March 11, 2004 Thursday 4:10 pm – 6:10 pm

Note:

1. There are totally four problems. Please label answer for each problem clearly.

2. Please use only the standard blue color exam book. Only answers written on your exam book will be graded. Remember to write your name clearly on the cover page.

3. Open books and notes. Use of calculator is OK. But computers and cellular phones are not allowed.

4. Best luck!

P.1 (Sampling) (15%)

One model of high definition television (HDTV) uses 1125 horizontal lines and the picture aspect ratio (width-to-height) is 16:9. It uses the interlaced format with each field being 1/60 second in duration. Suppose when we digitize such signal, we use the same horizontal-to-vertical resolution ratio as the ratio described above. Typically, each color component (i.e., R, G, B) of a pixel is encoded with 8 bits.

Calculate the total number of bits needed for storing a 2 hour video program.

P.2 (Quantization) (30%)

A signal, *u*, is modeled as a random variable with the following probability density function, P_u

$$P_u = \begin{cases} 1/3, & -1 \le u < -1/2 \\ 2/3, & -1/2 \le u < 1/2 \\ 1/3, & 1/2 \le u < 1 \end{cases}$$

we want to design a two-level quantizer using the following two approaches.

(a) Compandor Design

First convert *u* to a new random variable *w* which has a uniform probability density function over [-1,1]. Use a uniform quantizer for *w* and then map it back to the domain of *u*.

Derive the mapping functions between *u* and w, and the decision and reconstruction values of the quantizers for *u* and *w*.

(b) Approximation as Gaussian Distribution

In this approach, we approximate P_u as a Gaussian distribution with the same mean and standard deviation. From the table of optimal MSE quantizer for Gaussian, we know the optimal 2-level quantizer for Gaussian with zero mean and unit standard deviation has the following values:

$$t_0 = -\infty, \quad t_1 = 0, \quad t_2 = \infty, \quad r_0 = -0.7979, \quad r_1 = 0.7979$$

Use the above values to design the optimal MSE 2-level quantizer for *u* .

P.3 (High-Pass Filtering and DFT) (30%)

Laplacian operator uses the 2nd order derivative, $\nabla^2 f = \frac{\partial^2 f}{\partial x^2}$, to estimate the magnitude of the spatial variation at a point. A popular method based on Laplacian for enhancing the image quality is called "high-frequency emphasis". It can be modeled by the following equation.

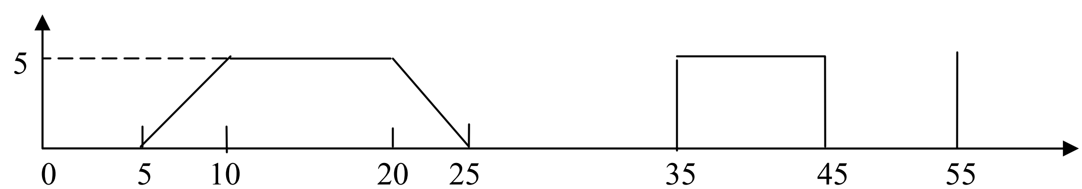
$$g = f - \nabla^2 f$$

(a) Laplacian operator, $\nabla^2 f$ is often implemented in the spatial domain with the following mask

$$[1 \quad -2 \quad 1].$$

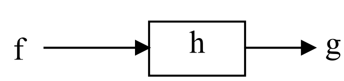
Note the origin corresponds to the center of the mask.
Derive the corresponding spatial-domain mask that can be used to compute g.

(b) Suppose the input signal f(x) has the following shape



Use the spatial-domain mask derived in (a) to compute the output of the high-frequency emphasis process. Plot the output and indicate all the important values.

(c) We can model the high-frequency emphasis process as a linear filter like the one shown below.



Derive the Discrete Fourier Transform of the filter, h.

Plot the spectrum and explain that indeed it is a good approximation of the spectrum of the Laplacian operation in the frequency domain.

P.4 (Image Quality Enhancement) (25%)

Assume you are given an image that suffers from the following problems related to image quality.

- The image does not have enough contrast. Most areas in the image appear to be too bright.
- The structures and boundaries in the image are blurred and thus it is hard to see the details of objects in the image.
- There are random sparse black spots (pepper noise) that seem to be caused by some electronics noises.

You are asked to propose a system that use techniques you have learned in this class to improve the overall image quality.

Please design a conceptual diagram for a quality enhancement system that addresses all the problems mentioned above. Provide justifications for the use of each component and the specific order you adopt in combining different components. Try to provide as much information as needed. For example, if you use contrast stretching, specify the shape of the intensity mapping function. If you use sharpening filters, specify the specific type of filter you will use.