Digital Image Processing Laboratory: Image Filtering

October 12, 1998

Introduction

In this laboratory, you will filter full color images using both FIR and IIR filters, and you will learn to use the program *xv* to display process and print your images. We will also use Matlab to plot various functions.

All programs used to process images in this laboratory should be written in the C programming language. Low level programming languages are necessary for implementing many complex image processing operations, so one objective of this laboratory is to give you some experience in using C to solve image processing problems. Simple example programs are provided, so you should be able to write the required programs even if you have very little previous experience with C.

When processing images on a computer, there are usually special cases that must be properly handled. In the laboratory, all filters should be implemented using a **free** boundary condition along the edges. Also, processing will sometimes cause a pixel to exceed the value 255 or go below the value 0. In these cases, you should clip the pixel's value.

$$y(m,n) = \begin{cases} y(m,n) = 0 & \text{if } x(m,n) < 0 \\ y(m,n) = 255 & \text{if } x(m,n) > 255 \\ y(m,n) = x(m,n) & \text{if } 0 \le x(m,n) \le 255 \end{cases}$$

Questions or comments concerning this laboratory should be directed to Prof. Charles A. Bouman, School of Electrical and Computer Engineering, Purdue University, West Lafayette IN 47907; (765) 494-0340; bouman@ecn.purdue.edu

1 Using XV

Your first task is to use the program *xv3.10* to load, manipulate and print an image.

1. First load the image *img12.tif* from the laboratory home page.
2. Run the program xv3.10 by using the command
   xv3.10 &
   Click the third mouse button in the image window. This will bring up the xv controls window. Select the load button. Then double click on *img12.tif*.
3. Save the image as as a gray scale (achromatic) image named *gray.tif*. Do this by selecting the save button, and choosing *Grayscale* on the pull-down menu. Load the image *gray.tif* and compare it to the color image.
4. Reload the color image *img12.tif*, and reduce image to half size by selecting *Half Size* under the *Image Size* menu.
5. Save the image as postscript, and then print it out on the HP ColorLaserJet 5M printer.

Section 1 Report:
Hand in a color print out from item 5 above.

2 FIR Low Pass Filter

In this problem, you will analyze and implement a simple low pass filter given by the 9×9 point spread function

$$h(m,n) = \begin{cases} 1/81 & \text{for } |m| \leq 4 \text{ and } |n| \leq 4 \\ 0 & \text{otherwise} \end{cases} .$$

1. Calculate an analytical expression for $H(e^{j\mu}, e^{j\nu})$ the DSFT of $h(m,n)$, and use Matlab to plot the magnitude of the frequency resposne $|H(e^{j\mu}, e^{j\nu})|$. Make sure to label the axis properly and plot on over the region $[-\pi, \pi] \times [-\pi, \pi]$.
2. Load the directory *C-code* containing the C source code for reading an writing tagged image file format (TIFF) images. Compile the application *Example* using an ANSI C compiler.
3. Run the program *Example* on the image *img03.tif* by using the command
   `Example img03.tif`
   This will produce the gray scale image "green.tif" which is derived from the green component of *img03.tif*.

4. Modify the program *Example* so that it filters the red, green and blue components of *img03.tif* with the filter $h(m,n)$ and generates a full color output image.

   Warning: Make sure to rename the directory containing your modified program so that it can not be overwriten with the original *Example* program directory.

5. Print out the resulting filtered image at one half normal size.

Section 2 Report:
Hand in:

1. A plot of $|H(e^{j\mu}, e^{j\nu})|$.
2. A color print out of *img03.tif*.
3. A color print out of the filtered image.
4. A listing of your C code.

3 FIR Sharpening Filter

In this problem, you will analyze the effect of a sharpening filter known as an unsharp mask. The terminology comes from the fact that an usharp mask filter removes the unsharp (low frequency) component of the image, and therefore produces an image with a sharper appearance.

Let $h(m,n)$ be a low pass filter. For our purposes use

$$h(m,n) = \begin{cases} 1/25 & \text{for } |m| \leq 2 \text{ and } |n| \leq 2 \\ 0 & \text{otherwise} \end{cases} .$$

The unsharp mask filter is then given by

$$g(m,n) = \delta(m,n) + \lambda(\delta(m,n) - h(m,n))$$

where λ is a constant greater than zero.

1. Calculate an analytical expression for $H(e^{j\mu}, e^{j\nu})$ the DSFT of $h(m,n)$, and use Matlab to plot the magnitude of the frequency resposne $|H(e^{j\mu}, e^{j\nu})|$. Make sure to label the axis properly and plot on over the region $[-\pi, \pi] \times [-\pi, \pi]$.

2. Calculate an analytical expression for $G(e^{j\mu}, e^{j\nu})$ the DSFT of $g(m,n)$. Use Matlab to plot $|G(e^{j\mu}, e^{j\nu})|$ for $\lambda = 0.8$. Make sure to label the axis properly and plot it over the region $[-\pi, \pi] \times [-\pi, \pi]$.

3. Modify the program *Example* so that it filters the red, green and blue components of *img03.tif* with the filter $g(m,n)$ and generates a full color output image. Write your modified code so that it takes a command line arguement that specifies the value of λ.

4. Apply your sharpening filter to *imgblur.tif* for $\lambda = 0.2, 0.8, 1.5$. Use *xv* to compare each result to the original image.

5. Print out the image for $\lambda = 0.8$ and hand in your matlab script used for filtering.

Section 3 Report:
Hand in:

1. A plot of $|H(e^{j\mu}, e^{j\nu})|$.
2. A plot of $|G(e^{j\mu}, e^{j\nu})|$ for $\lambda = 0.8$.
3. A color print out of *imgblur.tif*.
4. A color print out of the shapened image for $\lambda = 0.8$.
5. A listing of your C code.

4 IIR Filter

In this problem, you will analyze the effect of an IIR filter specified by a 2-D difference equation. Let $h(m, n)$ be the impulse response of an IIR filter with correponding difference equation

$$y(m, n) = 0.01x(m, n) + 0.9(y(m-1, n) + y(m, n-1)) - 0.81y(m-1, n-1) \ .$$

1. Calculate and analytical expression for $H(e^{j\mu}, e^{j\nu})$ the DSFT of $h(m, n)$, and use Matlab to plot the magnitude of the frequency resposne $|H(e^{j\mu}, e^{j\nu})|$. Make sure to label the axis properly and plot on over the region $[-\pi, \pi] \times [-\pi, \pi]$.

2. Compute the point spread function of the filter $100\, h(m, n)$ by filtering a 256×256 image of the form $x(m, n) = 255\delta(m - 127, n - 127)$. Print out the resulting point spread function image.

3. Modify the program *Example* so that it filters the red, green and blue components of *img03.tif* with the filter $h(m, n)$ and generates a full color output image.

4. Print out the resulting image.

Section 4 Report:

Hand in:

1. A plot of $|H(e^{j\mu}, e^{j\nu})|$.
2. A print out of the point spread function.
3. A color print out of the filtered image.
4. A listing of your C code.