Image Processing I

EECE 253 Fall 2011

Assignment 7: Image Processing with Mathematical Morphology

Due on or before 12:00 Midnight Wednesday 14 December 2011

The goals of this lab are to learn how to use Mathematical Morphology to perform (1) the fundamental binary operations, (2) the fundamental grayscale operations, (3) operations with large structuring elements, (4) quasi-highpass, small feature extraction, and (5) feature-preserving noise reduction using morphological reconstruction.

In this lab assignment (and all the others) you will be writing your own image processing functions. Except as specified below, you may not use the functions from the `Matlab` image processing toolkit by themselves or within your functions to solve the problems in the labs. You may compare the results of your own functions against those of the IP toolkit for your own information but those results may not be used in your lab reports.

Help can be gotten on any `Matlab` command (or function) by typing `help command_name`, *e.g.* to get help on `imwrite()`, type `help imwrite` at the command prompt. Another way is to press the <F1> key, select the **index** tab in the window, and type the command name into the search box.

In completing this assignment (and the others) if specific images are not supplied, you may use any images you like providing that they are of the type specified by the problem description (*e.g.* 24-bit truecolor). Please do not use images that are obscene or gruesome. In general, an image is OK if you could show it to your grandmother without upsetting her or embarrassing yourself. A wide variety of images are available under creative commons license on the web site `www.flickr.com`. If you are not the photographer, be sure to credit the person who did take the picture.

1. Preparations: Convert a truecolor image to grayscale then binary.

   (a) Write a program to extract the NTSC weighted luminance from any truecolor image. The formula is E-Z:

   $$L = 0.299R + 0.587G + 0.114B,$$

   where R, G, and B are the red, green, and blue bands of the image. Describe the reason for the unequal weighting.

   Find a truecolor image with high contrast that pictures at least one distinct foreground object. (The image should be somewhat noisy or cluttered so that you can most easily see the results of the morphological operations that follow. I suggest you use an image of dimensions about 512^2 to keep the computation time low.) Use the program to convert it to grayscale. Show the original image and the results.

(b) Write a program to *threshold* a monochrome (grayscale) image. This also is E-Z:

$$B(r,c) = \begin{cases} 255 & \text{if} \quad I(r,c) \geq t, \\ 0 & \text{if} \quad I(r,c) < t. \end{cases}$$

Threshold the grayscale image from the previous problem using the program. Choose a threshold that, as much as possible separates the foreground objects from the background.

2. Write programs to perform the basic morphological operations on binary images. Your programs should include an argument to select one of the three following structuring elements (SE).

$$Z_8 = \begin{bmatrix} 255 & 255 & 255 \\ 255 & 255 & 255 \\ 255 & 255 & 255 \end{bmatrix} \quad Z_4 = \begin{bmatrix} 0 & 255 & 0 \\ 255 & 255 & 255 \\ 0 & 255 & 0 \end{bmatrix} \quad Z_L = \begin{bmatrix} 255 & 0 \\ 255 & 0 \\ 255 & 255 \end{bmatrix} \tag{1}$$

Assume the origin of each SE is the center pixel, $Z(2,2)$, indexing from 1 *a la* `Matlab`. Assume that 0 is the background value and 255 is the foreground. Your programs should operate on binary images of any size.

The programs are:

(a) **Binary Dilate.** You may implement any of the equivalent definitions.

(b) **Binary Erode.** Write this using the Binary Dilate function.

(c) **Binary Open.** Write this using the Binary Dilate and Binary Erode functions.

(d) **Binary Close.** Write this using the Binary Dilate and Binary Erode functions.

For each part (a)–(d), above:

(i) Test the corresponding program on the 26×11 test image,
`Lab7_BinMorphTestImg.bmp`
using structuring element Z_L. Check your result with image
`Lab7_BinMorphExamples.bmp`.
Note that in the cross-hatched areas your programs may return different values – that's OK. Why?

(ii) Include the result of the test in your report.

(iii) Operate on the binary image from 1(b) using structuring element Z_L.

(iv) Display the result in your report. Also include the same small region from the original and processed images, nearest-neighbor enlarged, so the individual pixels are clearly visible. You may need to choose a different region to display for each operation to see the results.

3. Write programs to perform the basic morphological operations on grayscale images. Your programs should include an argument to select one of the three following structuring elements (SE).

$$Z_8 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad Z_4 = \begin{bmatrix} -\infty & 0 & -\infty \\ 0 & 0 & 0 \\ -\infty & 0 & -\infty \end{bmatrix} \quad Z_L = \begin{bmatrix} 0 & -\infty \\ 0 & -\infty \\ 0 & 0 \end{bmatrix} \tag{2}$$

Assume the origin of each SE is the center pixel, $Z(2,2)$, indexing from 1 *a la* `Matlab`. Assume that $-\infty$ is the background value and 0 is the foreground. Your programs should operate on grayscale images of any size.

The programs are:

(a) **Grayscale Dilate.** You may implement any of the equivalent definitions.

(b) **Grayscale Erode.** Write this using the Grayscale Dilate function.

(c) **Grayscale Open.** Write this using the Grayscale Dilate and Grayscale Erode functions.

(d) **Grayscale Close.** Write this using the Grayscale Dilate and Grayscale Erode functions.

For each part (a)–(d), above:

(i) Test the corresponding program on the 26×11 test image, `Lab7_GrayMorphTestImg.bmp` using structuring element Z_L. Check your result with image `Lab7_GrayMorphExamples.bmp`. Note that in the cross-hatched areas your programs may return different values – that's OK.

(ii) Include the result of the test in your report.

(iii) Operate on the grayscale image from 1(a) using structuring element Z_L.

(iv) Display the result in your report. Also include the same small region from the original and processed images, nearest-neighbor enlarged, so the individual pixels are clearly visible. You may need to choose a different region to display for each operation to see the results.

4. Two of the many algorithmic results from mathematical morphology are

$$I \oplus \{Z_1 \oplus Z_2 \oplus \cdots \oplus Z_n\} = I \oplus Z_1 \oplus Z_2 \oplus \cdots \oplus Z_n,$$

and

$$I \ominus \{Z_1 \oplus Z_2 \oplus \cdots \oplus Z_n\} = I \ominus Z_1 \ominus Z_2 \ominus \cdots \ominus Z_n.$$

This means that successive dilation or erosion by a set of structuring elements is the same as dilation or erosion by a single structuring element made by dilating the SEs in the set by each other. In other words, the dilation or erosion of an image by a large SE can be accomplished by dilating or eroding the image with an appropriate sequence of small SEs.

(a) In this problem you will open and close the binary image as follows:

$$\begin{aligned} J &= I \circ Z \\ &= I \ominus Z_8 \ominus Z_4 \ominus Z_8 \ominus Z_4 \oplus Z_8 \oplus Z_4 \oplus Z_8 \oplus Z_4, \end{aligned} \tag{3}$$

and

$$\begin{aligned} J &= I \bullet Z \\ &= I \oplus Z_8 \oplus Z_4 \oplus Z_8 \oplus Z_4 \ominus Z_8 \ominus Z_4 \ominus Z_8 \ominus Z_4. \end{aligned} \tag{4}$$

Display and describe the result in your report.

(b) This problem is identical to problem 4a, but use your grayscale operators on your grayscale image, G, to compute $G \circ Z$ and $G \bullet Z$ using Z from problem 4a. Again you will have to iterate erosions and dilations of G with Z_4 and Z_8 to compute them. Display both images and comment on their appearances. What types of features have been removed by the processes?

5. Small feature extraction:

   (a) Compute the tophat, $TH\{B; Z\} = B - (B \circ Z)$, and the bothat, $BH\{B; Z\} = (B \bullet Z) - B$, of the binary image, using your results from problem 4a. Display them both as a single grayscale image by computing $TH\{B; Z\} - BH\{B; Z\}$ and normalizing the result so that $-255 \to 0$, $0 \to 128$, and $255 \to 255$.

   (b) This problem is identical to problem 5a, using the grayscale image, G, and your results from problem 4b.

6. Morphological reconstruction:

   (a) Perform morphological reconstruction on the binary image you created in problem 4a. Use it as the starting image, *I.e.*, as image J in step 1 of the algorithm in Lecture 17 pg 48. Display and describe the results.

   (b) Perform morphological reconstruction on the grayscale image you created in problem 4b. Use it as the starting image, *I.e.*, as image J in step 1 of the algorithm in Lecture 18 pg 42. Display and describe the results.

7. There is no additional problem for graduate students in this lab assignment.

Rules for assignments

1. All work must be yours and yours alone. Collaboration on the assignments is forbidden, with the following exceptions:

   (a) You may obtain help on any aspect of the homework from either Prof. Peters or the TAs for this course.

   (b) You may obtain technical help on the *programming language* you are using from anyone you wish.

   (c) You may get help in obtaining the *input* images for the assignments from anyone you wish.

   (d) You may get help in the formatting or storing or transmission of your reports from anyone you wish.

   (a) Explain the tasks you performed in detail.

   (b) Include in the report the original image you used and those resultant images that I specified above.

   (c) Include all computer code that you wrote and used, clearly documented, in an appendix.

   (d) Write your results in a clear laboratory report format using MS Word, WordPerfect, LaTeX, or any other word processor with which you can embed images in text. Name the file which contains your report:

   `YourName_eece253_F2005_Assignment_5.doc`

   or `.pdf` or .whatever depending on the file type. Please upload your report file to blackboard.