Vanderbilt University
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EECE 253 IMAGE PROCESSING

LABORATORY ASSIGNMENT 4

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Abstract

This paper reports the results of experiments done to explore mathematical morphology in both binary images and gray scale images. Mathematical morphology is an extremely useful set of operations that us underused. It can be used for image enhancement, edge detection, skeletonization, and many more operations. In this lab, dilate, erode, open and close functions were written for both binary and gray scale images. Dilate and erode are the base operations in all of morphology, and in fact, they can be defined in terms of each other. These functions were used to do small feature extraction and morphological reconstruction. The usefulness and speed of mathematical morphology is demonstrated throughout this report.

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Introduction

Performing mathematical morphological operations on images can provide us much insight into the qualities of the image. It can be used for edge or feature detection, as well as for removing noise from an image. These techniques are demonstrated below throughout this lab report.

Description of Experiments

There were six experiments performed in this lab. Matlab was used for all the computation. All the scripts that were written can be found in the appendix and in the zip file this report came in. The results were somewhat subjective and discussions can be found in the report below.

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 5122 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: 255 if I(r,c)≥t, B(r,c) = 0 if I(r,c) < t. 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). 255255255 0 255 0 255 0 Z8=255 255 255 Z4=255 255 255 ZL=255 0 (1) 255 255 255 0 255 0 255 255 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 ZL. 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 ZL. (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 struc- turing elements (SE). 0 0 0 ¡∞ 0 ¡∞ 0 ¡∞ Z8=000Z4= 0 0 0 ZL=0¡∞ (2) 0 0 0 ¡∞ 0 ¡∞ 0 0 Assume the origin of each SE is the center pixel, Z (2, 2), indexing from 1 a la Matlab. Assume that ¡∞ 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 ZL. 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 ZL. (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

$I \oplus \{Z1 \oplus Z2 \oplus \cdots \oplus Zn\} = I \oplus Z1 \oplus Z2 \oplus \cdots \oplus Zn$, and $I \ominus \{Z1 \oplus Z2 \oplus \cdots \oplus Zn\} = I \ominus Z1 \ominus Z2 \ominus \cdots \ominus Zn$.

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: $J = I \circ Z$ and $= I \ominus Z8 \ominus Z4 \ominus Z8 \ominus Z4 \oplus Z8 \oplus Z4 \oplus Z8 \oplus Z4$, (3) $J = I \bullet Z = I \oplus Z8 \oplus Z4 \oplus Z8 \oplus Z4 \ominus Z8 \ominus Z4 \ominus Z8 \ominus Z4$. (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 Z4 and Z8 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 ◦ Z), and the bothat, BH{B;Z} = (B • Z) ¡ B, of the binary image, using your results from problem 4a. Display them both as a single grayscale image by computing T H{B; Z} ¡ BH{B; Z} and normalizing the result so that ¡255 → 0, 0 → 128, and 255 → 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 prob- lem 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.

Results of Experiments

Experiment 1

a) In this experiment a program was written that would convert a true color image to grayscale. This was done using the NTSC standard, which does not apply equal weighting to each band. This is because our eye is more sensitive to certain colors, so they need to be weighed differently in the conversion. The formula can be seen in the section above.

The following image was used throughout the lab. Below it you can see the results of the conversion to grayscale.

Figure 1. Image used throughout the lab

Figure 2. Image converted to gray scale.

b) To convert the gray scale image to binary it must be thresholded. A threshold of 150 was chosen to best separate the foreground from the background.

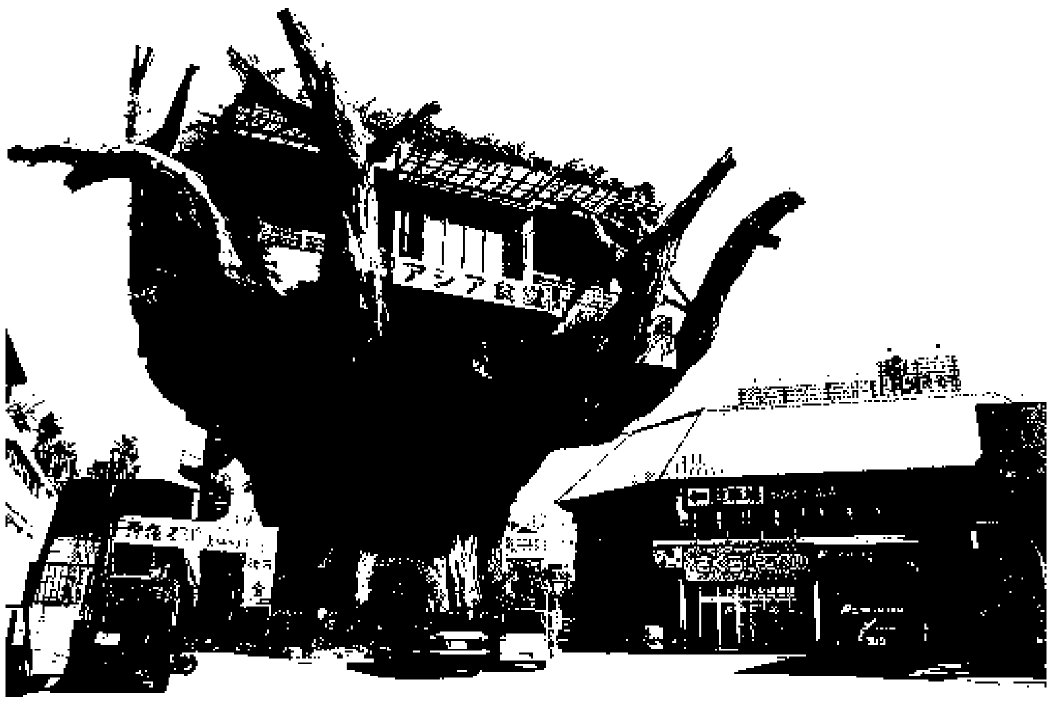

Figure 3. Threshold image.

Experiment 2

The basic operations of binary morphology were programmed in this experiment; Dilate, Erode, Open, and Close. The results of the operations can be seen below.

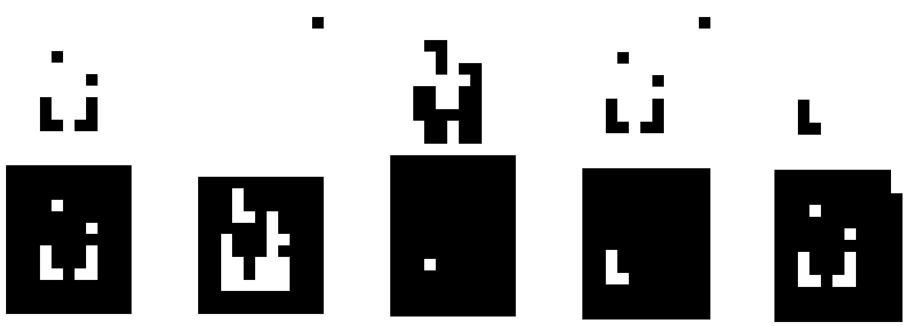

Figure 4-8. Original Dilated Eroded Opened Closed

The threshold image from experiment 1 was also run through each operation. Below are the results. Note that due to the thresholding the treehouse and buildings were set as black, and the sky was set as white. This may make the operations seem incorrect, but that is just because the treehouse is the background and the sky is the foreground.

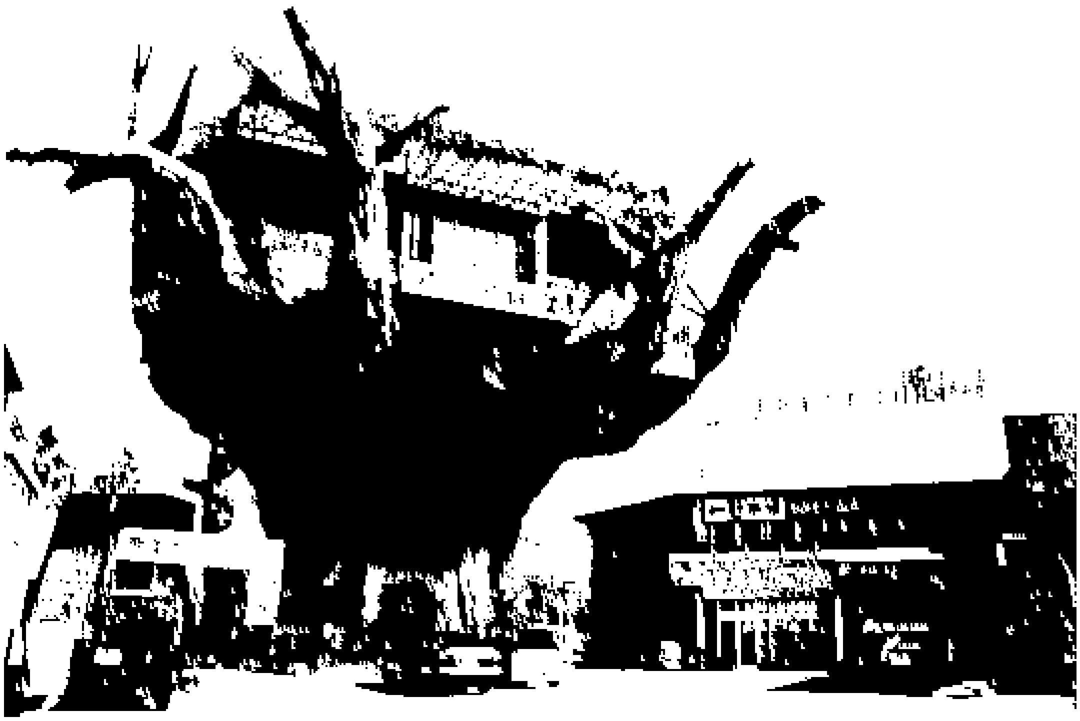

Figure 9. Dilated image

Figure 10. Eroded image

Figure 11. Opened image

Figure 12. Closed image.

To see more detail, zoomed in regions of the above images are shown below.

Figure 13-16. Enlarged sections of dilated, eroded, opened, and closed images respectively

Experiment 3

This experiment is the same as above, but using grayscale morphology instead of binary. Below is the test image and the result after being run through each operation, using the Z_L structuring element.

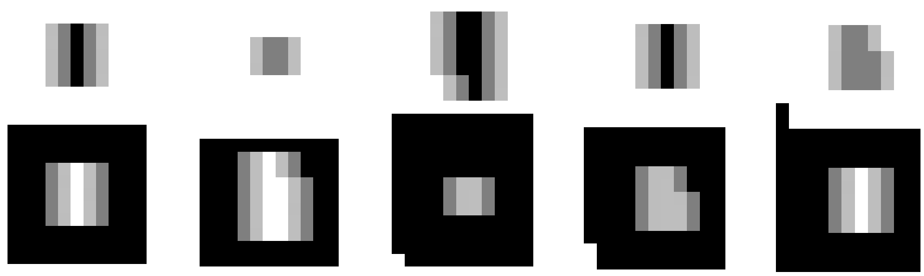

Figure 17-21. Original Dilated Eroded Opened Closed

To see the effects of these operations on a larger objects, the image in figure 2 was used. The results are detailed below.

Figure 22. Dilated image

Figure 23. Eroded image

Figure 24. Opened image

Figure 25. Closed image

To see more detail, zoomed in regions of the above images are shown below

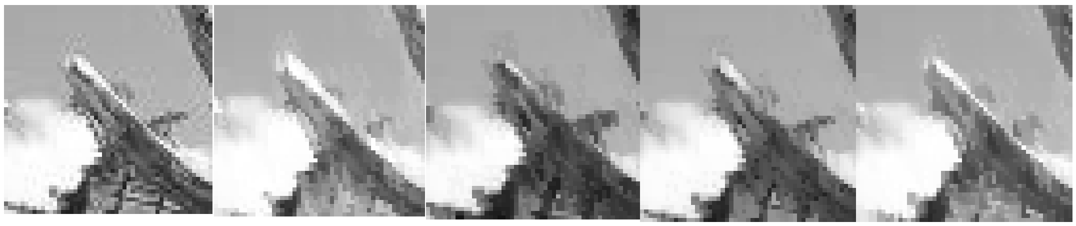

Figure 25-30. Zoomed in regions of Original, Dilated, Eroded, Opened, and Closed images

Experiment 4

This experiment demonstrates that dilation or erosion by a large SE can be broken down into successive dilations or erosions of smaller SEs.

a) The image was put through the binary open function and the binary close function by applying successive erodes and dilations as described in the Description of Experiments. Below are the results

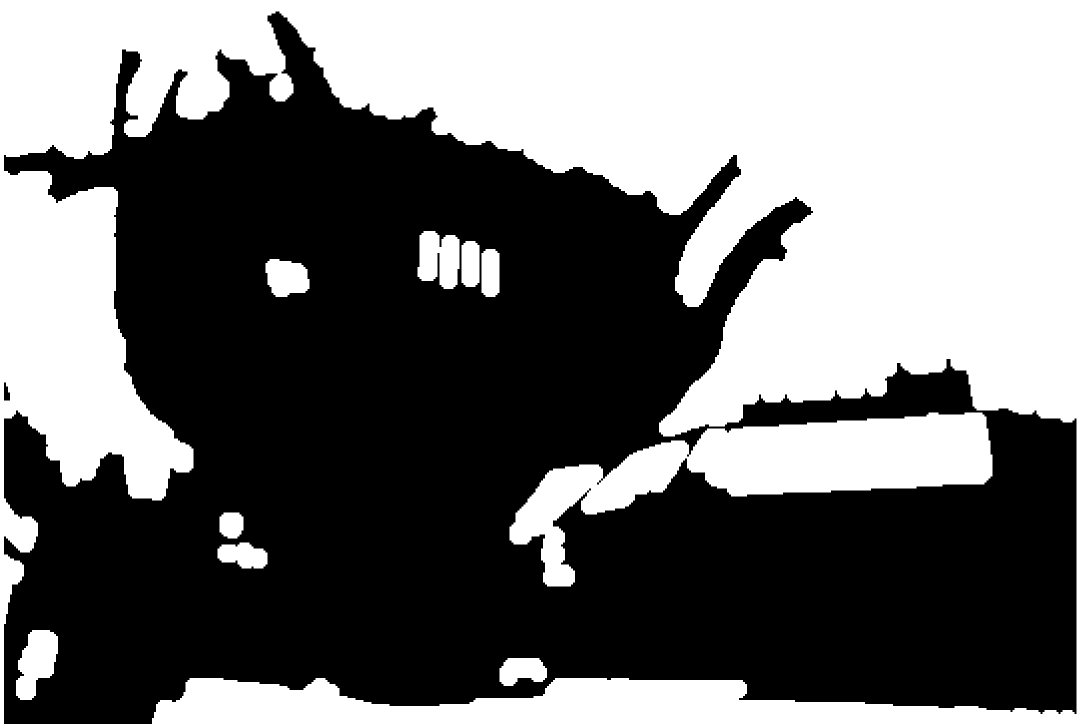

Figure 31. Binary open applied as a series of erodes and dilations

Figure 32. Binary close applied as a series of erodes and dilations

b) This is the same as part a), except using grayscale morphology instead of binary.

Figure 33. Grayscale open applied as a series of erodes and dilations

Figure 34. Grayscale close applied as a series of erodes and dilations

In both of the parts above, all of the fine detail has been removed, and many of the shapes were connected. The grayscale images look like they have been blurred and then sharpened.

Experiment 5

This experiment explored small feature extraction. This is done by finding a difference image between the opened and closed images from the previous experiment. Since the above operations removed small features, finding the difference should single them out. The tophat and bothat are both shown in the same image by normalizing everything to be between 0 and 255. (0 is set to 127)

a)

Figure 35. Binary tophat and bothat both shown in the same image

b)

Figure 36. Grayscale tophat and bothat both shown in the same image.

Experiment 6

Morphological reconstruction was explored in this experiment. This is a method of removing noise by eroding it away, and then dilating the image until it fills out all the same pixels as the original. The results of binary and grayscale reconstruction can be seen below.

a)

Figure 37. Binary reconstruction

b)

Figure 38. Grayscale reconstruction.

As you can see above, the images appear much smoother, and all extraneous pixels have been removed.

Conclusion

Each of these experiments explored different aspects of mathematical morphology. The first experiment simply dealt with conversion to grayscale and binary from a true color image. The second and third experiments demonstrated how to program the basic operations of all morphology, dilation and erosion. The experiments that followed demonstrated some useful properties of these operations and a few techniques that can be used to extract useful information from an image, such as small features and edges.