Segmentation and Region Extraction

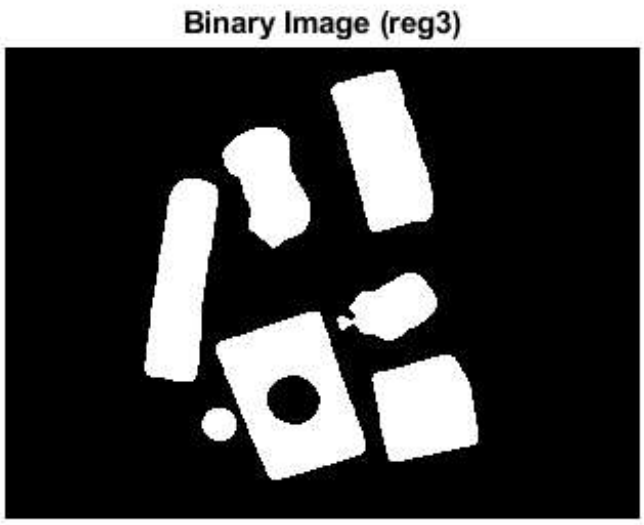
Image 1 - Get Regions

- **Import and crop image.**

```
reg3 = imread('reg3.jpg');
reg3 = reg3(6:(end-5), 6:(end-5));
[H, W] = size(reg3);
figure, imshow(reg3), title("Original Image (reg3)");
```

- **Threshold image with niblack algorithm and noise reduction.**

```
reg3 = niblack(reg3, 81, -0.1);
reg3 = gaussfilter(uint8(reg3*255), 5, 2);
reg3 = (reg3 > floor(255/2));
figure, imshow(reg3), title("Binary Image (reg3)");
```



- **Extract Connected Regions.**

```
reg3 = raster_regioning(reg3);
figure, imshow(label2rgb(reg3)), title("Segmented Image (reg3)");
```


```
labels = unique(reg3);
```

Image 1 - Get Statistics

```
for i = 2:length(labels)

    lbl = labels(i);

    % mask out other objects:
    obj = reg3;
```

```
    obj(obj ~= lbl) = false;
    obj = logical(obj);

    % start display:
    %figure, imshow(obj), title("Object ID: " + num2str(lbl));
    disp("Statistics for Object with ID: " + num2str(lbl));

    % create img with holes of object filled in:
    obj_filled = fill_img(obj);

    % create img with just holes of the object:
    holes_img = obj_filled - obj;
    holes_img = raster_regioning(holes_img);

    % find number of holes that have been regioned out:
    hole_num = length(unique(holes_img)) - 1; % subtract one for background.

    % Find Area, MBR, and Centroid:
    [maxX, maxY] = deal(-inf);
    [minX, minY] = deal(inf);
    [total_x, total_y, n, nf, p] = deal(0);
    for row = 1:H
        for col = 1:W
            if (obj(row, col)) % check actual object image

                n = n + 1;

                if(col > maxX)
                    maxX = col;
                end
                if(col < minX)
                    minX = col;
                end
                if(row > maxY)
                    maxY = row;
                end
                if(row < minY)
                    minY = row;
                end

                total_x = total_x + col;
                total_y = total_y + row;
            end

            if (obj_filled(row, col)) % check filled-in object image
                nf = nf + 1;
                if perimeter_pixel(obj_filled, row, col)
                    p = p + 1;
                end
            end
        end
    end
```

```
    disp("    Area = " + num2str(n));

    disp("    Number of Holes = " +num2str(hole_num));

    disp("    Area of Holes = " + num2str(nf - n));

    disp("    MBR = ");
    disp("      minX = " + num2str(minX));
    disp("      minY = " + num2str(minY));
    disp("      maxX = " + num2str(maxX));
    disp("      maxY = " + num2str(maxY));

    disp("    Centroid = ");
    disp("      [x,y] = [" + num2str(total_x/n) + ", " + num2str(total_y/n) + "]");

    disp("    Perimeter = " + num2str(p));

    disp("    Elongation = " + num2str( (p^2)/n ));
end
```

```
Statistics for Object with ID: 1
    Area = 2518
    Number of Holes = 0
    Area of Holes = 0
    MBR =
      minX = 160
      minY = 12
      maxX = 209
      maxY = 90
    Centroid =
      [x,y] = [185.5278, 50.9797]
    Perimeter = 254
    Elongation = 25.6219
Statistics for Object with ID: 11
    Area = 1565
    Number of Holes = 0
    Area of Holes = 0
    MBR =
      minX = 107
      minY = 40
      maxX = 149
      maxY = 98
    Centroid =
      [x,y] = [129.3284, 67.2818]
    Perimeter = 202
    Elongation = 26.0728
Statistics for Object with ID: 23
    Area = 2375
    Number of Holes = 0
    Area of Holes = 0
```

```
    MBR =
      minX = 69
      minY = 65
      maxX = 104
      maxY = 163
    Centroid =
      [x,y] = [86.8046, 115.0147]
    Perimeter = 266
    Elongation = 29.792
Statistics for Object with ID: 37
    Area = 962
    Number of Holes = 2
    Area of Holes = 21
    MBR =
      minX = 163
      minY = 111
      maxX = 211
      maxY = 143
    Centroid =
      [x,y] = [189.762, 127.5509]
    Perimeter = 166
    Elongation = 28.6445
Statistics for Object with ID: 56
    Area = 3364
    Number of Holes = 1
    Area of Holes = 475
    MBR =
      minX = 104
      minY = 130
      maxX = 176
      maxY = 211
    Centroid =
      [x,y] = [140.8083, 170.2562]
    Perimeter = 306
    Elongation = 27.8347
Statistics for Object with ID: 78
    Area = 2049
    Number of Holes = 0
    Area of Holes = 0
    MBR =
      minX = 180
      minY = 151
      maxX = 231
      maxY = 202
    Centroid =
      [x,y] = [205.8365, 176.7545]
    Perimeter = 204
    Elongation = 20.3104
```

```
Statistics for Object with ID: 91
    Area = 217
    Number of Holes = 0
    Area of Holes = 0
    MBR =
      minX = 97
      minY = 177
      maxX = 113
      maxY = 192
    Centroid =
      [x,y] = [105.2028, 184.4101]
    Perimeter = 62
    Elongation = 17.7143
```

Image 2 - Get Regions

- **Import and crop image.**

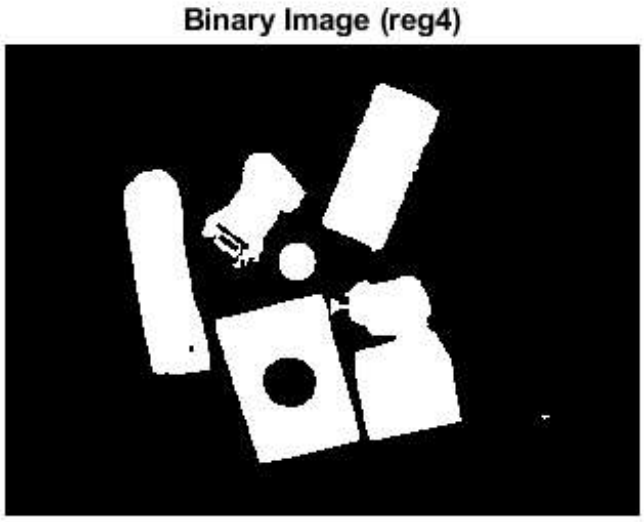
```
reg4 = imread('reg4.jpg');
reg4 = reg4(6:(end-5), 6:(end-5));
[H, W] = size(reg4);
figure, imshow(reg4), title("Original Image (reg4)");
```

- **Threshold image with niblack algorithm and noise reduction.**

```
reg4 = niblack(reg4, 80, -0.1);
reg4 = gaussfilter(uint8(reg4*255), 5, 0.7);
reg4 = (reg4 > floor(255/2));

reg4 = bwmorph(reg4, 'diag');
reg4 = bwmorph(reg4, 'clean');
reg4 = bwmorph(reg4, 'fill');
```

```
figure, imshow(reg4), title("Binary Image (reg4)");
```



- **Extract Connected Regions.**

```
reg4 = raster_regioning(reg4);
figure, imshow(label2rgb(reg4)), title("Segmented Image (reg4)");
```


```
labels = unique(reg4);
```

Image 2 - Get Statistics

```
for i = 2:length(labels)

    lbl = labels(i);
```

```
% mask out other objects:
obj = reg4;
obj(obj ~= lbl) = false;
obj = logical(obj);

% start display:
%figure, imshow(obj), title("Object ID: " + num2str(lbl));
disp("Statistics for Object with ID: " + num2str(lbl));

% create img with holes of object filled in:
obj_filled = fill_img(obj);

% create img with just holes of the object:
holes_img = obj_filled - obj;
holes_img = raster_regioning(holes_img);

% find number of holes that have been regioned out:
hole_num = length(unique(holes_img)) - 1; % subtract one for background.

% Find Area, MBR, and Centroid:
[maxX, maxY] = deal(-inf);
[minX, minY] = deal(inf);
[total_x, total_y, n, nf, p] = deal(0);
for row = 1:H
    for col = 1:W
        if (obj(row, col)) % check actual object image

            n = n + 1;

            if(col > maxX)
                maxX = col;
            end
            if(col < minX)
                minX = col;
            end
            if(row > maxY)
                maxY = row;
            end
            if(row < minY)
                minY = row;
            end

            total_x = total_x + col;
            total_y = total_y + row;
        end

        if (obj_filled(row, col)) % check filled-in object image
            nf = nf + 1;
            if perimeter_pixel(obj_filled, row, col)
                p = p + 1;
            end
        end
    end
```

```
    end

    disp("    Area = " + num2str(n));

    disp("    Number of Holes = " +num2str(hole_num));

    disp("    Area of Holes = " + num2str(nf - n));

    disp("    MBR = ");
    disp("      minX = " + num2str(minX));
    disp("      minY = " + num2str(minY));
    disp("      maxX = " + num2str(maxX));
    disp("      maxY = " + num2str(maxY));

    disp("    Centroid = ");
    disp("      [x,y] = [" + num2str(total_x/n) + ", " + num2str(total_y/n) + "]");

    disp("    Perimeter = " + num2str(p));

    disp("    Elongation = " + num2str( (p^2)/n ));
end
```

```
Statistics for Object with ID: 1
    Area = 2485
    Number of Holes = 0
    Area of Holes = 0
    MBR =
      minX = 156
      minY = 20
      maxX = 212
      maxY = 101
    Centroid =
      [x,y] = [183.9111, 59.8322]
    Perimeter = 277
    Elongation = 30.8769
Statistics for Object with ID: 17
    Area = 1295
    Number of Holes = 7
    Area of Holes = 96
    MBR =
      minX = 97
      minY = 54
      maxX = 147
      maxY = 109
    Centroid =
      [x,y] = [122.9629, 79.3305]
    Perimeter = 217
    Elongation = 36.3622
Statistics for Object with ID: 25
    Area = 2666
```

```
    Number of Holes = 2
    Area of Holes = 8
    MBR =
      minX = 59
      minY = 62
      maxX = 100
      maxY = 161
    Centroid =
      [x,y] = [78.132, 113.1995]
    Perimeter = 280
    Elongation = 29.4074
Statistics for Object with ID: 62
    Area = 263
    Number of Holes = 0
    Area of Holes = 0
    MBR =
      minX = 135
      minY = 98
      maxX = 152
      maxY = 115
    Centroid =
      [x,y] = [143.1445, 106.4677]
    Perimeter = 68
    Elongation = 17.5817
Statistics for Object with ID: 73
    Area = 3080
    Number of Holes = 3
    Area of Holes = 51
    MBR =
      minX = 160
      minY = 114
      maxX = 223
      maxY = 193
    Centroid =
      [x,y] = [193.7877, 154.7987]
    Perimeter = 333
    Elongation = 36.0029
Statistics for Object with ID: 84
    Area = 3417
    Number of Holes = 1
    Area of Holes = 495
    MBR =
      minX = 104
      minY = 123
      maxX = 173
      maxY = 204
    Centroid =
      [x,y] = [139.0632, 163.2865]
```

```
    Perimeter = 300
    Elongation = 26.3389
Statistics for Object with ID: 111
    Area = 5
    Number of Holes = 1
    Area of Holes = 46
    MBR =
      minX = 263
      minY = 182
      maxX = 266
      maxY = 183
    Centroid =
      [x,y] = [264.4, 182.2]
    Perimeter = 51
    Elongation = 520.2
```

Discussion:

Thresholding Method: Since these were fairly complex grayscale images with multiple forground objects of differing intensities, I thought it would be best to implement a local thresholding algorithm. This algorithm computes a threshold for every pixel depending on the window of pixels surrounding it. The specific algorithm that I followed was the Niblack Algorithm. While I could not find the original paper by Niblack, I did find the mathematic algorithm on page 2 of "Efficient Implementation of Niblack Thresholding for MRI Brain Image Segmentation " by Senthilkumaran N and Kirubakaran C. I've sent the paper in with this report.

After doing this local thresholding I noticed that the images were still a bit noisy. So I implemented a basic gaussian smoothing convolution function and used this to smooth out any irregularities and noise. This process alone worked very well for the first image. However, as you can see from my results of preprocessing image 2, I had a lot of problem separating objects from there shadows on the table. This caused 2 of the objects to be melded together in the binary image as if they were one object. This problem could have been solved by using a smaller window for local thresholding and perhaps using a smaller gaussian kernal for smoothing, but in this case and other manipulations of these parameters, I found that the noise was far too great. So I decided to cut my losses and deal with this mis-information with minimal noise. Addtionally in the second image, I encountered some problems when facing very bright protions of objects. These portions were considered holes or concavities by the thresholding algorithm as there didn't seem to be enough information to differentiate them from the color of the table in the background.

Finally, for the second image I also used some of matlabs basic morphilogical functions to help clean up some of the noise. These were very basic functions that I did not see any need to reimplement them myself.

Extract Connected Regions: For this method I used the basic 2-pass raster method that we talked about in class. the slight modification that I made was that I prepadded the image so that I could reference pixels outside the original image for testing and not get an index out of bounds error. This did not affect the algorithm since all added pad rows and columns were all zeros. Once the region extraciton was finished I unpadded the image before returning it. I then used matlabs label2rgb() display function to color each region a different color in the display image. Before extracting statistics

for each object I used the objects ID to mask out any other objects that might be present in the image. I then converted the now single object image to a logical matrix.

Area: This was simply computed adding up all the 1s in the single object image.

Number of Holes: For this statistic I used the following method:

- First fill in all the holes of the single object image with a signle raster scan.
- Subtract the original image from this filled in image. We now have an image that is 1's where the holes are and 0's everywhere else.
- I then preformed the same raster_regioning that was used to extract regions. This then tells me how many regions were recognized by looking at the holes.

Area of Holes: This was simply computed by summing all the 1s of the difference of the two images described in the previous statistic.

MBR: This was simply found by constantly updating the largest and smallest x and y values that were found to be in the object when doing a raster scan.

Centroid: Found by [total_x_coords / Area, total_y_coords/ Area]

Perimeter: This statistic was found by taking the previosly described single object image with all the holes filled in, and then simply counting up all the pixels that have any neighboring pixels that are not part of the object in a single raster scan.

Elongation: Perimeter^2 / Area.

Overall I think the first image was very successful with my methods, but the second image posed some problems with thresholding. This is due to a lack of information in the image (perhaps using rgb would have better helped determine forground objects) and due to my thresholding algorithm not being robust enough to separate all the objects correctly without any noise. However, the gathering of the image statistics worked well independent of the thresholding problems.