1 Part 1: Thresholding

1.1 Introduction

Thresholding is a technique used to segment an image based on grey level intensities within the image. Two common methods of thresholding an image are applying a "Fixed Global Threshold" and applying an "Adaptive Threshold". Each of these methods take a greyscale input image, and output a binary (black and white) image.

Fixed Global thresholding involves applying a single threshold value across the image, i.e. if the intensity value of the pixel is greater than the threshold value, set that pixel to white, otherwise, set it to black.

Adaptive thresholding techniques base their threshold values at the current pixel off the neighbouring pixels. The "5x5 Adaptive Thresholding" method utilised in this section takes the mean intensity value of the 24 pixels surrounding the currently selected pixel as the threshold value for the currently selected pixel. If this center pixels intensity value is greater than the threshold, it's value is set to white, otherwise it is set to black.

1.2 Techniques

In completing this section of the assignment, the following techniques are utilised:

1.2.1 Part a

Load Image

Matlabs "imread()" function is used to load an image, whose filename is passed as an argument to the function, as an array in the form $X \times Y \times 3$ where X and Y are the dimensions of the image, and the "3" represents the colour channels (RGB).

Colour to Greyscale

The Matlab "rgb2gray()" function converts a colour image to a greyscale image. The three channel RGB image is converted to a single channel greyscale image based on the luminance of each pixel in the image. The output single channel values range from $0 - 255$.

Show Image

The Matlab "imshow()" function is used to display an image on screen.

1.2.2 Part b

Threshold

The VSG "Threshold" function applies a fixed global threshold to the input image. If the pixel value is less than the threshold value, the pixel is set to black, otherwise it is set to white.

1.2.3 Part c

5x5 Threshold

The VSG "5x5Thresh" function applies an adaptive 5x5 threshold to the image. The function defaults to a threshold offset of value zero.

When the value of the center pixel in the 5x5 region is less than the mean of the 5x5 region minus the offset, the pixel is set to black, otherwise it is set to white.

1.2.4 Part d

Gaussian Noise The Matlab "imnoise()" function, when used with the 'gaussian' input parameter, applies Gaussian noise with mean specified by input parameter 'm', and variance 'var', e.g:

```
imnoise(img1, 'gaussian', 0, var)
```

The above example applies zero-mean Gaussian noise to the image "img1", with a variance "var".

1.3 Pseudocode

1.3.1 Part a

1. Load the image into Matlab using the "imread()" function
2. Use the "rgb2gray()" function to convert the image to greyscale.
3. Display the greyscale image using the "imshow()" function.

1.3.2 Part b

1. Follow the steps of Part a.
2. Apply a fixed global threshold using the VSG package "Threshold" function. An arbitrary value should be chosen for the fixed threshold value.

3. Vary the fixed threshold value in order to obtain optimal background/-foreground segmentation, while retaining facial features.

4. Display the thresholded images using the “imshow()” function.

1.3.3 Part c

1. Follow the steps of Part a.

2. Apply a 5x5 adaptive threshold using the VSG package "5x5Thresh" function.

3. Display the adaptive thresholded image using the “imshow()” function.

1.3.4 Part d

1. Follow the steps of Part a.

2. Apply Gaussian noise to the greyscale image using the MIP “imnoise()” function. Zero-mean noise should be used for this section.

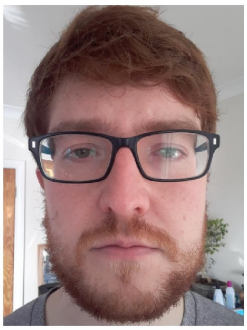
3. Execute the fixed global thresholding and 5x5 adaptive thresholding procedures as described in part b and part c respectively.

4. Adjust the variance value of the “imnoise()” function. Repeat steps 2 and 3.

1.4 Results

1.4.1 Part a

The image is correctly loaded into Matlab, converted to greyscale, and displayed. The input image is of dimensions $512 \times 348 \times 3$, and is of data type integer. This means that the image is in the RGB colour space, with the red, green, and blue channels represented by a value of 0-255 for each pixel in the image. The resulting greyscale image is of dimensions 512×384 and is also of type integer. The single channel representing the greyscale intensities have values ranging from 0-255.



(a) Input Image

(b) Greyscale Image

Figure 1: Input and Greyscale Images

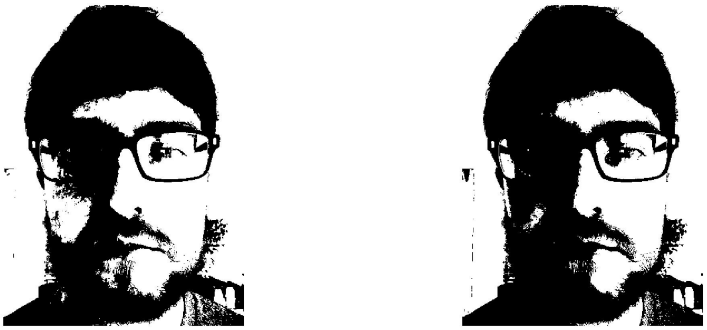
1.4.2 Part b

The VSG "Threshold" function is applied, with varying threshold values, to the input greyscale image. The "Threshold" function returns images with the same dimensions as the input image, however the data type returned is "double" rather than "integer". The initial value of the threshold is 199, calculated by taking !!!!!!!!!. As this threshold does not provide adequate separation of the features in the image, arbitrary values of 125, 130, and 140 are also used. The image thresholded at 125 has the greatest level of separation between the face and background, while also retaining as much detail as possible in the facial features.

(a) Data Driven Threshold

(b) Threshold= 125

Figure 2: "Threshold" Function Output



(a) Threshold= 130 (b) Threshold= 140

Figure 3: "Threshold" Function Output

1.4.3 Part c

The VSG "5x5Thresh" function is applied to the input greyscale image. The resulting image is of type "double" and has the same dimensions as the input image. When compared with the fixed global threshold images, there is much greater separation of the foreground from the background, with all of the facial features fully visible. Features which are thresholded out due to lighting conditions in the fixed global threshold are retained here, such as the eyes.

Figure 4: "5x5Thresh" Function Output

1.4.4 Part d

Gaussian noise is added to the greyscale image, and the "Threshold" and "5x5Thresh" functions are applied. As can be observed from the images, the fixed global threshold is less sensitive to noise. This is due to the 5x5 Threshold using the average value of an area of pixels to set the threshold value. As such, noise

within an area can skew the result of the thresholding, making this function much more sensitive to noise.

(a) Noisy Image (b) Global Threshold (c) 5x5 Threshold

Figure 5: Thresholded Images after Gaussian Noise (0.0001 Variance)

(a) Noisy Image (b) Global Threshold (c) 5x5 Threshold

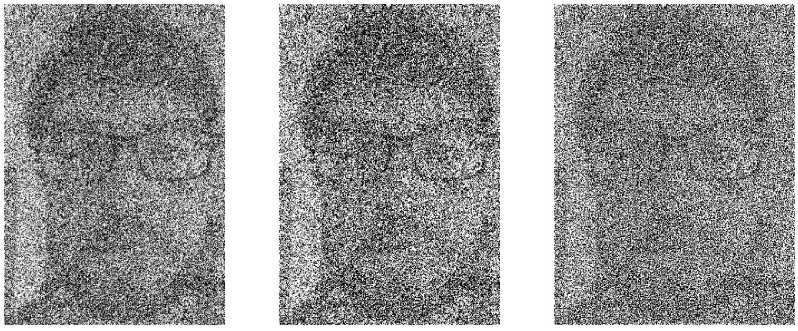
Figure 6: Thresholded Images after Gaussian Noise (0.001 Variance)

(a) Noisy Image (b) Global Threshold (c) 5x5 Threshold

Figure 7: Thresholded Images after Gaussian Noise (0.01 Variance)

(a) Noisy Image (b) Global Threshold (c) 5x5 Threshold

Figure 8: Thresholded Images after Gaussian Noise (0.1 Variance)



(a) Noisy Image (b) Global Threshold (c) 5x5 Threshold

Figure 9: Thresholded Images after Gaussian Noise (1 Variance)

It can be seen that until a variance of approximately

1.5 Conclusion

2 Part 2: Segmentation

2.1 Introduction

Segmentation is the practice of extracting features from an image. In this section, the main alphanumeric registration characters of a licence plate must be extracted from the overall image. The extracted characters must not include either the country code, county name, or dashes between sections of the registration.

Automated and data driven segmentation can be achieved by combining arithmetic functions and blob functions. As the size ratio of each letter in the registration does not change with scale, this ratio can be utilised to remove only blobs under a size specified by the largest letter (blob).

2.2 Techniques

2.2.1 Part a

Low Pass Filter

The VSG "LowPass" filter function applies a 3x3 low pass filter to the image.

Mid-Threshold

Much like the aforementioned "Threshold" function, the "MidThresh" function applies a single threshold value to the image. The threshold value chosen is 125, the middle of the 0-255 range of the integer input values.

Inversion (NOT)

Inversion is achieved using the VSG "NOT" function, which performs a boolean Not operation on each pixel of the image. On a binary image, this changes all white pixels to black, and all black pixels to white.

Biggest Blob

The "BiggestBlob" function of the VSG toolbox outputs an image containing only the biggest single white blob from the binary input image.

Subtract

The VSG "Subtract" function performs matrix subtraction between the specified images. Each pixel of the input image has its value subtracted from the corresponding pixel in the other image. As in this section, if one image is binary, and the other RGB colour, the binary image is subtracted from the red channel of the RGB image.

White Pixel Counter

The VSG "WPCounter" function counts the number of white pixels within the input image, outputting its value as an integer.

Mask

The VSG "MaskImg" function applies a border mask of the input thickness to the image. The masked pixels which fall within the thickness have their values set to 0 (black).

Exclusive Or (XOR)

The Exclusive Or function is completed using the VSG "XOR" function. A bitwise XOR operation applied to binary images returns a white pixel only if the pixel is white in exactly one of the two input images.

Count Blobs The "CountBlobs" function of the VSG toolbox counts the number of white blobs in the input image, outputting its value as an integer.

Canny

The VSG "Canny" edge detection function returns the image with any edges highlighted.

Add

The VSG "Add" function performs matrix addition between the specified images. Each pixel of the input image has its value added to the corresponding pixel in the other image. As in this section, if one image is binary, and the other RGB colour, the binary image is added to the red channel of the RGB image.

2.3 Pseudocode

2.3.1 Part a

1. Load the image into Matlab using the "imread()" function
2. Use the "rgb2gray()" function to convert the image to greyscale.
3. Display the greyscale image using the "imshow()" function.
4. Apply a low pass filter, using the VSG "LowPass" function, to remove noise from the image.
5. Apply a threshold to the image using the VSG "MidThreshold" function.

6. Invert the image using the VSG "NOT" function.
7. Extract the biggest blob (Country code and outer border), using the "BiggestBlob" VSG function.
8. Subtract the extracted biggest blob image from the original image using the VSG "Subtract" function.
9. Extract the biggest blob, using the "BiggestBlob" function, (the largest alphanumeric character in the registration) .
10. Using the VSG package "WPCounter" function, count the number of pixels in the biggest blob.
11. Apply a single pixel mask to the image in order to remove the white pixel border.
12. Compare the next biggest blob with the biggest blob, if the size is within the given ratio, "XOR" this with the image containing the previous biggest blob. Subtract this blob from the original image to avoid unintended looping. Repeat until the blob checked does not match the given ratio.
13. Count the number of blobs in the resulting image using the VSG "Count-Blobs" function.
14. Use the VSG 'Canny' function to output an edge detector representation of the extracted characters.
15. Overlay the resulting image on the original input image using the VSG 'Add' function.

2.3.2 Part b

1. Apply "imnoise()" to the greyscale image, repeating the steps in part a.
2. Increase the variance until the incorrect output value is acquired.

2.4 Results

2.4.1 Part a

In part a, the alphanumeric registration characters of the licence plate are correctly extracted. The licence plate image is first loaded into Matlab, converted to greyscale, and a low pass filter is applied.

(a) Input Image (b) Greyscale Image (c) Low Pass Filtered

Figure 10: Initial Segmentation Setup

The extraction process begins by applying a mid-value threshold to the image. The image is then inverted to allow for blob functions to be utilised. The border and country code are removed from the image by subtracting the biggest blob from the thresholded image.

(a) Mid Threshold (b) Inverted (Not)

Figure 11: Preparing for Border Removal

(a) Biggest Blob (b) Biggest Blob Removed

Figure 12: Removed Outer Border

Finally the main alphanumeric characters are extracted by looping through the blobs in the image, until the lower bound for the blob size is exceeded. The found blobs are then counted, and an edge detected version of the image is overlayed on the original image for display purposes.

(a) Largest Character (b) Remaining Characters

Figure 13: Removed Largest Alphanumeric Character

(a) Loop 1 Result (b) Loop 2 Result (c) Loop 3 Result

Figure 14: Characters Extracted from Loops 1-3

(a) Loop 4 Result (b) Loop 5 Result (c) Loop 6 Result

Figure 15: Characters Extracted from Loops 4-6

(a) Canny Edge Detection

(b) Overlayed Images

Figure 16: Overlayed Extracted Characters

In order to test that this code is working as intended, a unit test file (q2patest.m) is executed. The original .m file is converted to a function, with the output being the number of characters found. An assertion within the unit test checks each test licence plate image against it's expected resulting number of characters.

2.4.2 Part b

2.5 Conclusion

3 Part 3: Convolution

3.1 Introduction

3.2 Techniques

3.3 Pseudocode

3.3.1 Part a

1. Load the image into Matlab using the "imread()" function.
2. Use the "rgb2gray()" function to convert the image to greyscale.
3. Load the template image into Matlab using the "imread()" function.
4. Use the "rgb2gray()" function to convert the image to greyscale.
5. Use the VSG "Rotate" function to obtain a 180° rotated copy of the template.
6. Apply convolution on the greyscale input image, using the greyscale template image, using the VSG "Convolution" funciton.
7. Apply convolution on the greyscale input image, using the rotated greyscale template image, using the VSG "Convolution" funciton.
8. Add the resulting images from the convolution functions.
9. Apply a data driven global threshold to the image using the "Threshold" function of the VSG toolbox.

10. Apply the VSG "Centroid" function to the thresholded image to attain a point at the center of each blob.
11. Use the "Point2Square" function of the VSG toolbox to turn each centroid point to a square, for ease of viewing in the overlayed display.
12. Overlay the squares on the original image by adding the "Point2Square" resulting image to the original input image, using the VSG "Add" function.

3.3.2 Part b

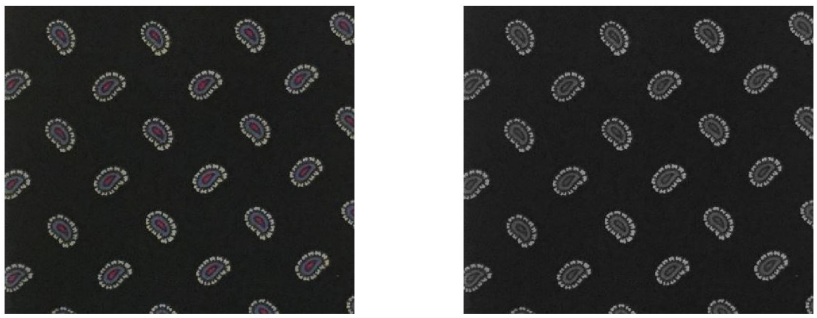
1. Repeat the steps described in Part a.
2. After the input image has been converted to greyscale, use the "MaskImg" function to cover any parts of the image in contact with the edge.
3. After the "Centroid" function is executed, add a call to the "WPCounter" function, to count the white pixels, thus giving the number of template matches within the image.

3.3.3 Part c

1. Follow the steps in Part a.
2. Apply Gaussian noise to the greyscale input image using the "imnoise()" function.
3. Adjust the variance of the "imnoise()" function until the count of template matches is no longer correct.

3.4 Results

3.4.1 Part a

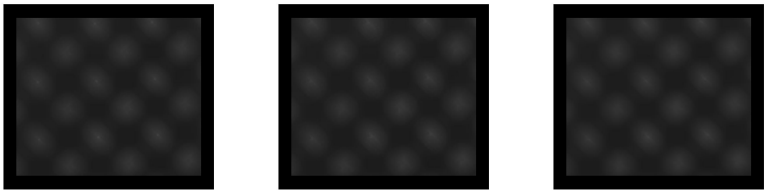


(a) Input Image (b) Input Greyscale Image

Figure 17: Input image and Greyscale Conversion

(a) Template Image (b) Greyscale Template (c) Template Rotated

Figure 18: Required Template for Convolution



(a) Convolution (OT) (b) Convolution (RT) (c) Convolution (+)

Figure 19: Convolution outputs: Original Template(OT), Rotated Template(RT), Added Results(+)

(a) Threshold (b) Centroid (c) Point2Square

Figure 20: Outputs from the "Threshold", "Centroid", and "Point2Square" Functions, showing the locations of templte matches

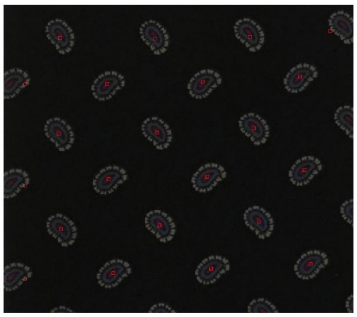
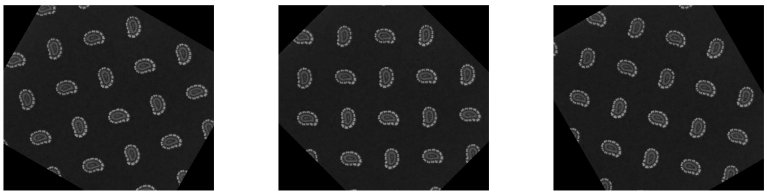
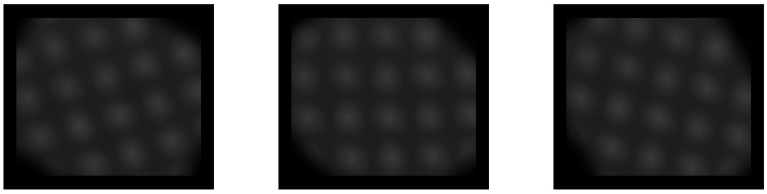


Figure 21: Overlay showing Location of Pattern Matches



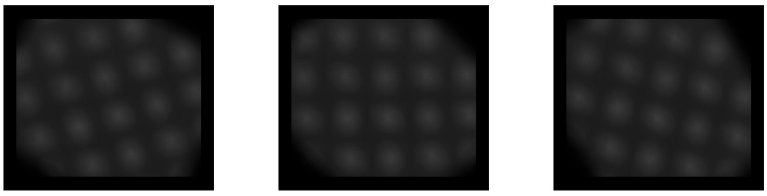
(a) Input 30° (b) Input 45° (c) Input 60∘

Figure 22: Input Image Rotated $30°, 45°$ & $60°$



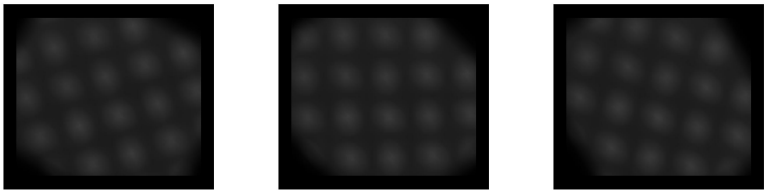
(a) Convolution1 30° (b) Convolution1 45° (c) Convolution1 60∘

Figure 23: Convolution with Template: $30°, 45°$ & $60°$



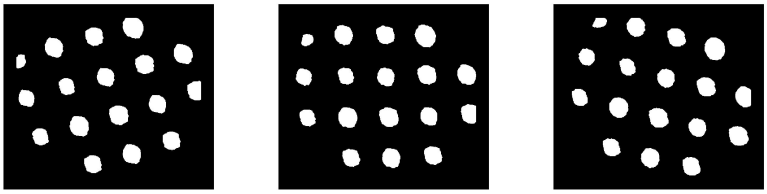
(a) Convolution2 30° (b) Convolution2 45° (c) Convolution2 60∘

Figure 24: Convolution with Rotated Template: $30°, 45°$ & $60°$



(a) Added Convolution 30° (b) Added Convolution 45° (c) Added Convolution 60∘

Figure 25: Added Convolution Results: $30°, 45°$ & $60°$

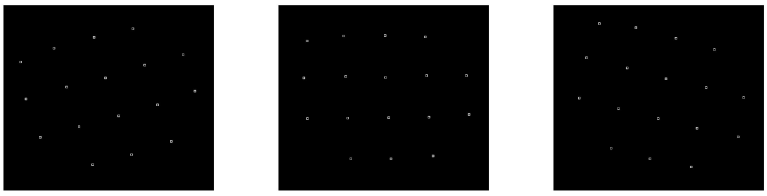


(a) Threshold 30° (b) Threshold 45° (c) Threshold 60∘

Figure 26: Threshold: $30°, 45°$ & $60°$

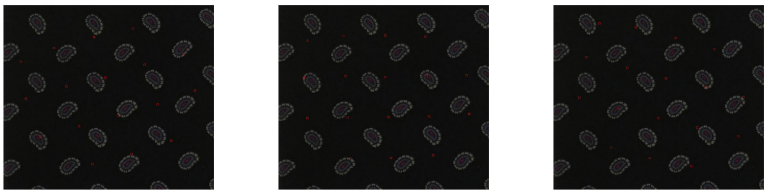
(a) Centroid 30° (b) Centroid 45° (c) Centroid 60∘

Figure 27: Centroid: $30°, 45°$ & $60°$



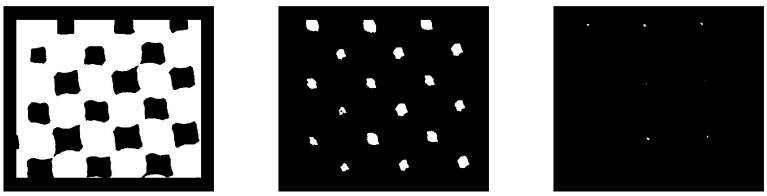
(a) Point2Square 30° (b) Point2Square 45° (c) Point2Square 60∘

Figure 28: Point2Square: $30°, 45°$ & $60°$



(a) Overlay 30° (b) Overlay 45° (c) Overlay 60∘

Figure 29: Overlay: $30°, 45°$ & $60°$



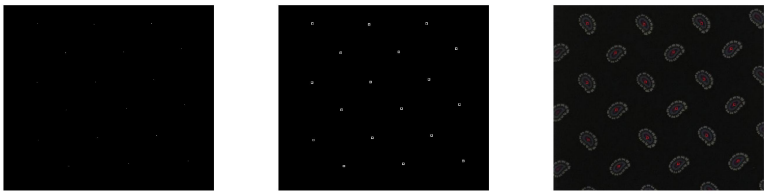
(a) Threshold Value 32 (b) Threshold Value 50 (c) Threshold Value 60

Figure 30: Convolution Thresholded at Values: 32, 50, & 60

3.4.2 Part b

(a) Dilated Image (b) Convolution (c) Threshold

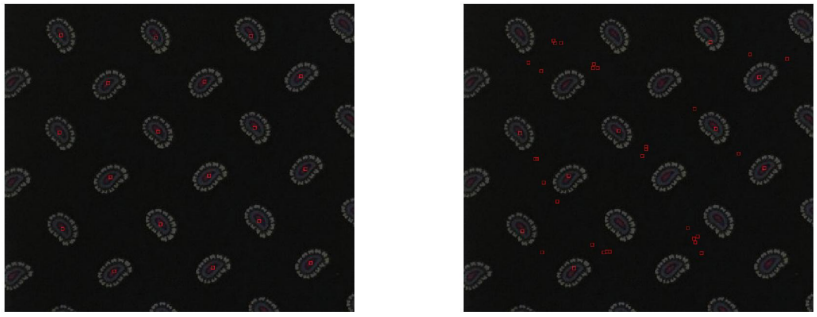
Figure 31: Dilation, Convolution and Thresholding Applied to Input Image



(a) Centroid (b) Point2Square (c) Overlay

Figure 32: Overlay of Template Match on Original Input Image

3.4.3 Part c



(a) Noise Variance at 0.01 (b) Noise Variance at 0.1

Figure 33: Overlay showing correct template matching at 0.01 variance, and incorrect matching at 0.1 variance.

3.5 Conclusion

4 Appendix

4.1 Part 1:

4.1.1 Code:

Listing 1: Part 1 a

```
% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');
```

```
% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
A_COL = imread('face.jpg');
A_COL = uint8(vsg('Rotatep90', A_COL));
disp('Image read done');

% Display Image
h=figure;
imshow(uint8(A_COL));
set(h,'Name','Input Image');
saveas(h, 'Results\Q1\a\qaInput.jpg')

% Convert to greyscale and display the result
A=rgb2gray(A_COL);
h=figure;
imshow(uint8(A));
set(h,'Name','Greyscale Input');
saveas(h, 'Results\Q1\a\qaGreyscale.jpg')


% Wait for "Any key input" before deleting all figures
pause;
close all force;
```

Listing 2: Part 1 b

```
% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
A_COL = imread('face.jpg');
A_COL = uint8(vsg('Rotatep90', A_COL));
disp('Image read done');

% Display Image
h=figure;
imshow(uint8(A_COL));
set(h,'Name','Input Image');
```

```
% Convert to greyscale and display the result
A=rgb2gray(A_COL);
h=figure;
imshow(uint8(A));
set(h,'Name','Greyscale Input');

% Data driven threshold based on the max/min of the image
    histogram
hi_grey=vsg('HighestGrey',A);
disp('Highestgrey done');
lo_grey=vsg('LowestGrey',A);
disp('Lowestgrey done');
thresh=uint8(3*(hi_grey+lo_grey)/4);

% Output the calculated threshold to the command window
string=['Data driven threshold is ' num2str(thresh)];
disp(string);

% Apply a fixed global threshold to the image and display
    the resultant binary image
C=vsg('Threshold',A,thresh);
h=figure;
imshow(uint8(C));
set(h,'Name','Threshold Data Drive');
saveas(h, 'Results\Q1\b\qbThreshData.jpg')

D=vsg('Threshold',A,125);
h=figure;
imshow(uint8(D));
set(h,'Name','Threshold 125');
saveas(h, 'Results\Q1\b\qbThresh125.jpg')

E=vsg('Threshold',A,130);
h=figure;
imshow(uint8(E));
set(h,'Name','Threshold 130');
saveas(h, 'Results\Q1\b\qbThresh130.jpg')

F=vsg('Threshold',A,140);
h=figure;
imshow(uint8(F));
set(h,'Name','Threshold 140');
saveas(h, 'Results\Q1\b\qbThresh140.jpg')

disp('Threshold done');
h=figure;
subplot(2,2,1), imshow(uint8(C));
subplot(2,2,2), imshow(uint8(D));
subplot(2,2,3), imshow(uint8(E));
subplot(2,2,4), imshow(uint8(F));
```

```
set(h,'Name','Threshold Image');

% Wait for "Any keey input" before deleting all figures
pause;
close all force;
```

Listing 3: Part 1 c

```
% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
A_COL = imread('face.jpg');
A_COL = uint8(vsg('Rotatep90', A_COL));
disp('Image read done');

% Display Image
h=figure;
imshow(uint8(A_COL));
set(h,'Name','Input Image');

% Convert to greyscale and display the result
A=rgb2gray(A_COL);
h=figure;
imshow(uint8(A));
set(h,'Name','Greyscale Input');

F=vsg('5x5Thresh',A,0);
h=figure;
imshow(uint8(F))
set(h,'Name','5x5 Threshold');
saveas(h, 'Results\Q1\c\qcThresh5x5.jpg')

% Wait for "Any keey input" before deleting all figures
pause;
close all force;
```

Listing 4: Part 1 d

```
% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
```

```
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
A_COL = imread('face.jpg');
A_COL = uint8(vsg('Rotatep90', A_COL));
disp('Image read done');

% Display Image
h=figure;
imshow(uint8(A_COL));
set(h,'Name','Input Image');

% Convert to greyscale and display the result
A=rgb2gray(A_COL);
h=figure;
imshow(uint8(A));
set(h,'Name','Greyscale Input');

i=.0001;
while i<10
    noiseFileName = strcat('Results\Q1\d\qdVar', num2str(
        i), '.jpg');
    ThreshFileName = strcat('Results\Q1\d\qdThresh',
        num2str(i), '.jpg');
    FiveThreshFileName = strcat('Results\Q1\d\qd5x5',
        num2str(i), '.jpg');

    B = imnoise(A, 'gaussian', 0, i);
    h=figure;
    imshow(uint8(B))
    set(h,'Name',noiseFileName);
    saveas(h, noiseFileName)

    % Apply the threshold to the image and display the
        resultant binary image
    E=vsg('Threshold',B,125);
    disp('Threshold done');
    h=figure;
    imshow(uint8(E));
    set(h,'Name','Threshold Image');
    saveas(h, ThreshFileName)

    % Mask boundary pixels to avoid any edge effects
    E=vsg('MaskImg',E,5);
```

```
    F=vsg('5x5Thresh',B,0);
    h=figure;
    imshow(uint8(F))
    saveas(h, FiveThreshFileName)


    i=i*10;
end;

% Wait for "Any key input" before deleting all figures
pause;
close all force;
```

4.2 Part 2:

4.2.1 Code:

Listing 5: Part 2 a

```
        % Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

i=1;
inputImage = 'number_plate_1';
saveDirectory = 'NumPlate1';
inputFileName = strcat('data\', inputImage, '.jpg');
saveFileName = strcat('Results\Q2\', saveDirectory, '\qa
    ', inputImage , '.jpg');
greyFileName = strcat('Results\Q2\', saveDirectory, '\qa
    ', inputImage , 'Grey.jpg');
lowFileName = strcat('Results\Q2\', saveDirectory, '\qa',
     inputImage , 'Low.jpg');
midFileName = strcat('Results\Q2\', saveDirectory, '\qa',
     inputImage , 'Mid.jpg');
notFileName = strcat('Results\Q2\', saveDirectory, '\qa',
     inputImage , 'Not.jpg');
borderFileName = strcat('Results\Q2\', saveDirectory, '\
    qa', inputImage , 'Border.jpg');
noBorderFileName = strcat('Results\Q2\', saveDirectory
    ,'\qa', inputImage , 'NoBorder.jpg');
bigCharFileName = strcat('Results\Q2\', saveDirectory ,'\
    qa', inputImage , 'BigChar.jpg');
```

```
remainCharsFileName = strcat('Results\Q2\', saveDirectory
    ,'\qa', inputImage , 'Remain.jpg');
addedCharFileName = strcat('Results\Q2\', saveDirectory
    ,'\qa', inputImage , 'Added', num2str(i), '.jpg');
cannyFileName = strcat('Results\Q2\', saveDirectory ,'\qa
    ', inputImage , 'Canny.jpg');
overlayFileName = strcat('Results\Q2\', saveDirectory ,'\
    qa', inputImage , 'Overlay.jpg');

% Read Sample Image
input_col = imread(inputFileName);
disp('Image read done');

% Display Image
h=figure;
imshow(uint8(input_col));
set(h,'Name','Input Image');
saveas(h, saveFileName)


% Convert to greyscale and display the result
in_img=rgb2gray(input_col);
h=figure;
imshow(uint8(in_img));
set(h,'Name','Greyscale Input');
saveas(h, greyFileName)


% Remove number plate border
[out_img1]=vsg('LowPass', in_img);
h=figure;
imshow(uint8(out_img1));
set(h,'Name','Low Pass Filtered Image');
saveas(h, lowFileName)

[out_img2]=vsg('MidThresh',out_img1);
h=figure;
imshow(uint8(out_img2));
set(h,'Name','MidThreshold Image');
saveas(h, midFileName)

[out_img3]=vsg('NOT',out_img2);
h=figure;
imshow(uint8(out_img3));
set(h,'Name','Inverted (NOT) Image');
saveas(h, notFileName)

[out_img4]=vsg('BiggestBlob',out_img3);
disp('BiggestBlob done');
%F=uint8(F);
```

```
h=figure;
imshow(uint8(out_img4));
set(h,'Name','BiggestBlob Image');
saveas(h, borderFileName)

[out_img5] = vsg('Subtract', out_img3, out_img4);
h=figure;
imshow(uint8(out_img5));
set(h,'Name','Subtracted Biggest Blob Image');
saveas(h, noBorderFileName)

% Extract number plate numbers
[out_img6] = vsg('BiggestBlob', out_img5);
h=figure;
imshow(uint8(out_img6));
set(h,'Name','Biggest Blob Image');
saveas(h, bigCharFileName)
[biggestBlobCounter] = vsg('WPCounter', uint8(out_img6))

[out_img5]=vsg('XOR', out_img5, out_img6);
% Remove 1 pixel white border from image.
[out_img5]=vsg('MaskImg', out_img5, 1);
h=figure;
imshow(uint8(out_img5));
saveas(h, remainCharsFileName)

while(vsg('WPCounter', vsg('BiggestBlob', out_img5))>(
    biggestBlobCounter/3))
  [tempBlob]=vsg('BiggestBlob', out_img5);
  h=figure;
  imshow(uint8(tempBlob));
  set(h,'Name','tempBlob');
  [biggestBlobCounter] = vsg('WPCounter', uint8(tempBlob)
      )
  [out_img6]=vsg('XOR', out_img6, tempBlob);
  h=figure;
  imshow(uint8(out_img6));
  addedCharFileName = strcat('Results\Q2\', saveDirectory
      ,'\qa', inputImage , 'Added', num2str(i), '.jpg');
  saveas(h, addedCharFileName)
  set(h,'Name','Remaining Blobs Image');
  [out_img5]=vsg('Subtract', out_img5, tempBlob);
  i=i+1;
end
% Count number of blobs in the image
% Corresponds to the number of digits on the number plate
[numBlobs] = vsg('CountBlobs', uint8(out_img6));
disp(numBlobs);

% Overlay the identified number plate numbers on
```

```
% the original input image
[out_img7, out_img8]=vsg('Canny', out_img6,  1.0, 5, 200)
    ;
h=figure;
imshow(uint8(out_img7));
set(h,'Name','Edge Detector Image');
saveas(h, cannyFileName)

[out_img9] = vsg('Add', out_img7, in_img);
h=figure;
imshow(uint8(out_img9));
set(h,'Name','Overlayed (Add) Image');
saveas(h, overlayFileName)

% Wait for "Any key input" before deleting all figures
pause;
close all force;
```

Listing 6: Part 2 b - Functions used to reduce lines of code

```
function numBlobs = p2qb(im_path, noise_var)

% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
%clc
%clear all


% Read Sample Image
input_col = imread(im_path);
disp('Image read done');

input_noisy = imnoise(input_col, 'gaussian', 0, noise_var
    );


% Display Image
% h=figure;
% imshow(uint8(input_col));
% set(h,'Name','Input Image');

% Convert to greyscale and display the result
in_img=rgb2gray(input_noisy);
% h=figure;
% imshow(uint8(in_img));
```

```
% set(h,'Name','Greyscale Input');

% Call Function to remove number plate border
[out_img1]=q2RemoveNumPlateBorder(in_img);

% Call Function to extract number plate numbers
[out_img2]=q2ExtractNumPlateNumbers(out_img1);

% Count number of blobs in the image
% Corresponds to the number of digits on the number plate
[numBlobs] = vsg('CountBlobs', uint8(out_img2));
disp(numBlobs);

% Overlay the identified number plate numbers on
% the original input image
[out_img3]=q2Overlay(out_img2, in_img);

% Wait for "Any key input" before deleting all figures
pause;
close all force;
end
```

Listing 7: Part 2 a Unit Test

```
clc;

%% Test Image 1

clear all;
assert(p2qa('data/number_plate_1.jpg')==7, 'Error in
    Output');

%% Test Image 2

clear all;
assert(p2qa('data/number_plate_2.jpg')==7, 'Error in
    Output');

%% Test Image 3

clear all;
assert(p2qa('data/number_plate_3.jpg')==6, 'Error in
    Output');

%% Test Image 4

clear all;
assert(p2qa('data/number_plate_4.jpg')==8, 'Error in
    Output');
```

```
%% Test Image 5

clear all;
assert(p2qa('data/number_plate_5.jpg')==7, 'Error in
    Output');

%% Test Image 6

clear all;
assert(p2qa('data/number_plate_6.jpg')==7, 'Error in
    Output');
```

Listing 8: Part 2 b Unit Test

```
clc
clear all

%% Test 1
i = 6;
assert(p2qb('data/number_plate_1.jpg', i)==7, 'Error in
    Output')
```

4.2.2 Images:

4.3 Part 3:

4.3.1 Code:

Listing 9: Part 3 a

```
        % Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
in_col = imread('data\tie.jpg');
disp('Image read done');
mask_col = imread('data\template_tie.jpg');

% Display Image
```

```
h=figure;
imshow(uint8(in_col));
set(h,'Name','Input Image');
saveas(h, 'Results\Q3\a\qaInput.jpg');

h=figure;
imshow(uint8(mask_col));
set(h,'Name','Input Kernel');
saveas(h, 'Results\Q3\a\qaTemplate.jpg');

% Convert to greyscale and display the result
in_img=rgb2gray(in_col);
% in_img=vsg('RotateImg', in_img, 30);
% in_img=vsg('RotateImg', in_img, 45);
% in_img=vsg('RotateImg', in_img, 60);

h=figure;
imshow(uint8(in_img));
set(h,'Name','Greyscale Input');
% saveas(h, 'Results\Q3\a\qaInputGrey.jpg');
% saveas(h, 'Results\Q3\a\qaInputRot30.jpg');
% saveas(h, 'Results\Q3\a\qaInputRot45.jpg');
% saveas(h, 'Results\Q3\a\qaInputRot60.jpg');

mask=rgb2gray(mask_col);
h=figure;
imshow(uint8(mask));
set(h,'Name','Greyscale Kernel');
saveas(h, 'Results\Q3\a\qaTemplateGrey.jpg');
mask_rot=vsg('RotateImg', mask, 180);
h=figure;
imshow(uint8(mask_rot));
set(h, 'Name', 'Rotated Greyscale Kernel');
saveas(h, 'Results\Q3\a\qaTemplateGreyRot.jpg');

[out_img1]=vsg('Convolution', in_img, mask);
h=figure;
imshow(uint8(out_img1));
% saveas(h, 'Results\Q3\a\qaConv1.jpg');
% saveas(h, 'Results\Q3\a\qaConv1-30.jpg');
% saveas(h, 'Results\Q3\a\qaConv1-45.jpg');
% saveas(h, 'Results\Q3\a\qaConv1-60.jpg');
[out_img2]=vsg('Convolution', in_img, mask_rot);
h=figure;
imshow(uint8(out_img2));
% saveas(h, 'Results\Q3\a\qaConv2.jpg');
% saveas(h, 'Results\Q3\a\qaConv2-30.jpg');
% saveas(h, 'Results\Q3\a\qaConv2-45.jpg');
% saveas(h, 'Results\Q3\a\qaConv2-60.jpg');
[out_img2]=vsg('Add', out_img1, out_img2);
```

```
h=figure;
imshow(uint8(out_img2));
% saveas(h, 'Results\Q3\a\qaAddedConv.jpg');
% saveas(h, 'Results\Q3\a\qaAddedConv30.jpg');
% saveas(h, 'Results\Q3\a\qaAddedConv45.jpg');
% saveas(h, 'Results\Q3\a\qaAddedConv60.jpg');

hi_grey=vsg('HighestGrey',out_img2);
disp('Highestgrey done');
lo_grey=vsg('LowestGrey',out_img2);
disp('Lowestgrey done');
thresh=uint8(3*(hi_grey+lo_grey)/4);
[out_img3]=vsg('Threshold', uint8(out_img2), thresh);
%[out_img3]=vsg('Threshold', uint8(out_img2), 60);
h=figure;
imshow(uint8(out_img3));
% saveas(h, 'Results\Q3\a\qaThresh.jpg');
% saveas(h, 'Results\Q3\a\qaThresh30.jpg');
% saveas(h, 'Results\Q3\a\qaThresh45.jpg');
% saveas(h, 'Results\Q3\a\qaThresh60.jpg');
% saveas(h, 'Results\Q3\a\qaThreshVal60.jpg');
[out_img4]=vsg('Centroid', out_img3);
h=figure;
imshow(out_img4);
% saveas(h, 'Results\Q3\a\qaCentroid.jpg');
% saveas(h, 'Results\Q3\a\qaCentroid30.jpg');
% saveas(h, 'Results\Q3\a\qaCentroid45.jpg');
% saveas(h, 'Results\Q3\a\qaCentroid60.jpg');
[out_img5]=vsg('Point2Square', out_img4);
h=figure;
imshow(uint8(out_img5));
% saveas(h, 'Results\Q3\a\qaP2S.jpg');
% saveas(h, 'Results\Q3\a\qaP2S30.jpg');
% saveas(h, 'Results\Q3\a\qaP2S45.jpg');
% saveas(h, 'Results\Q3\a\qaP2S60.jpg');
[out_img6]=vsg('Add', out_img5, in_col);
h=figure;
imshow(uint8(out_img6));
% saveas(h, 'Results\Q3\a\qaOverlay.jpg');
% saveas(h, 'Results\Q3\a\qaOverlay30.jpg');
% saveas(h, 'Results\Q3\a\qaOverlay45.jpg');
% saveas(h, 'Results\Q3\a\qaOverlay60.jpg');

% Wait for "Any key input" before deleting all figures
pause;
close all force;
```

Listing 10: Part 3 b

```
% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
in_col = imread('data\tie.jpg');
disp('Image read done');
mask_col = imread('data\template_tie.jpg');

% Display Image
h=figure;
imshow(uint8(in_col));
set(h,'Name','Input Image');

h=figure;
imshow(uint8(mask_col));
set(h,'Name','Input Kernel');

% Convert to greyscale and display the result
in_img=rgb2gray(in_col);
h=figure;
imshow(uint8(in_img));
set(h,'Name','Greyscale Input');

test=in_img;
test(2:size(in_img,1)-1,2:size(in_img,2)-1,:)=0;
h=figure;
imshow(uint8(test));
[dil1, dil2]=vsg('ReconByDil', in_img, test, 8);
h=figure;
imshow(uint8(dil2));
saveas(h, 'Results\Q3\b\qbDilation.jpg');

mask=rgb2gray(mask_col);
h=figure;
imshow(uint8(mask));
set(h,'Name','Greyscale Kernel');
mask_rot=vsg('RotateImg', mask, 180);

[out_img1]=vsg('Convolution', dil2, mask);
h=figure;
imshow(uint8(out_img1));
[out_img2]=vsg('Convolution', dil2, mask_rot);
h=figure;
imshow(uint8(out_img2));
```

```
saveas(h, 'Results\Q3\b\qbConvolution.jpg');

[out_img2]=vsg('Add', out_img1, out_img2);

hi_grey=vsg('HighestGrey',out_img2);
disp('Highestgrey done');
lo_grey=vsg('LowestGrey',out_img2);
disp('Lowestgrey done');
thresh=uint8(3*(hi_grey+lo_grey)/5);
[out_img3]=vsg('Threshold', uint8(out_img2), thresh);
h=figure;
imshow(uint8(out_img3));
saveas(h, 'Results\Q3\b\qbThreshold.jpg');

[out_img4]=vsg('Centroid', out_img3);
h=figure;
imshow(out_img4);
saveas(h, 'Results\Q3\b\qbCentroid.jpg');

numPatterns=vsg('WPCounter', out_img4);
[out_img5]=vsg('Point2Square', out_img4);
h=figure;
imshow(uint8(out_img5));
saveas(h, 'Results\Q3\b\qbP2S.jpg');

[out_img6]=vsg('Add', out_img5, in_col);
h=figure;
imshow(uint8(out_img6));
saveas(h, 'Results\Q3\b\qbOverlay.jpg');

% Wait for "Any key input" before deleting all figures
pause;
close all force;
```

Listing 11: Part 3 c

```
% Setup Paths to VSG Toolbox and Local Data
addpath('C:\VSG_IPA_toolbox');
addpath('D:\Documents\College\Masters\Semester1\EE453-
    ImageProcessingAndAnalysis\Personal\Assignment');

% Clear workspace and free up system memory
clc
clear all

% Read Sample Image
in_col = imread('data\tie.jpg');
disp('Image read done');
mask_col = imread('data\template_tie.jpg');
```

```
% Display Image
h=figure;
imshow(uint8(in_col));
set(h,'Name','Input Image');

h=figure;
imshow(uint8(mask_col));
set(h,'Name','Input Kernel');

% Convert to greyscale and display the result
in_img=rgb2gray(in_col);

test=in_img;
test(2:size(in_img,1)-1,2:size(in_img,2)-1,:)=0;
h=figure;
imshow(uint8(test));

i=0.0001;
while i<10
in_img1=imnoise(in_img, 'gaussian', 0, i);
h=figure;
imshow(uint8(in_img1));
saveas(h, strcat('Results\Q3\c\qcNoise', num2str(i), '.
    jpg'));
set(h,'Name','Greyscale Input');

[dil1, dil2]=vsg('ReconByDil', in_img1, test, 8);
h=figure;
imshow(uint8(dil2));
saveas(h, strcat('Results\Q3\c\qcDilation', num2str(i),
    '.jpg'));

mask=rgb2gray(mask_col);
h=figure;
imshow(uint8(mask));
set(h,'Name','Greyscale Kernel');
mask_rot=vsg('RotateImg', mask, 180);

[out_img1]=vsg('Convolution', dil2, mask);
h=figure;
imshow(uint8(out_img1));
[out_img2]=vsg('Convolution', dil2, mask_rot);
h=figure;
imshow(uint8(out_img2));
[out_img2]=vsg('Add', out_img1, out_img2);
h=figure;
imshow(uint8(out_img2));
saveas(h, strcat('Results\Q3\c\qcConv', num2str(i), '.jpg
    '));
```

```
hi_grey=vsg('HighestGrey',out_img2);
disp('Highestgrey done');
lo_grey=vsg('LowestGrey',out_img2);
disp('Lowestgrey done');
thresh=uint8(3*(hi_grey+lo_grey)/5);
[out_img3]=vsg('Threshold', uint8(out_img2), thresh);
h=figure;
imshow(uint8(out_img3));
saveas(h, strcat('Results\Q3\c\qcThresh', num2str(i), '.
    jpg'));
[out_img4]=vsg('Centroid', out_img3);
h=figure;
imshow(out_img4);
saveas(h, strcat('Results\Q3\c\qcCentroid', num2str(i),
    '.jpg'));

numPatterns=vsg('WPCounter', out_img4);
[out_img5]=vsg('Point2Square', out_img4);
h=figure;
imshow(uint8(out_img5));
saveas(h, strcat('Results\Q3\c\qcP2S', num2str(i), '.jpg
    '));

[out_img6]=vsg('Add', out_img5, in_col);
h=figure;
imshow(uint8(out_img6));
saveas(h, strcat('Results\Q3\c\qcOverlay', num2str(i), '.
    jpg'));

i=i*10;
end

% Wait for "Any key input" before deleting all figures
pause;
close all force;
```

4.3.2 Images: