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

A number of techniques are used in the completion of this assignment. As such each technique will only be introduced once, on it's first use. 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.

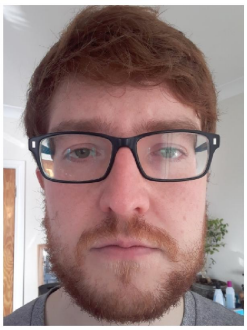
3. Execute the fixed global thresholding and 5x5 adaptive thresholding procedures as described in part b and part c respectively.

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

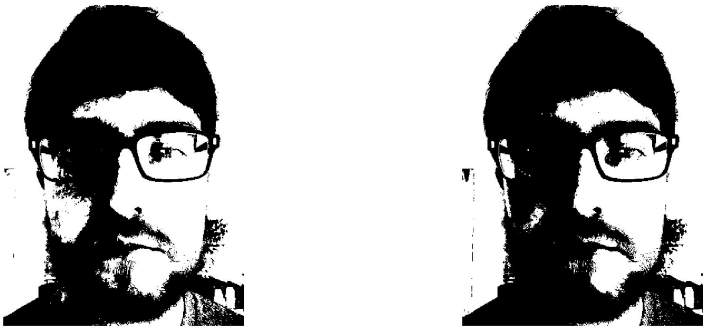
1.4.2 Part b

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 $\frac{3}{4} \times (HigghestGreyIntensity + LowestGreyIntensity)$.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

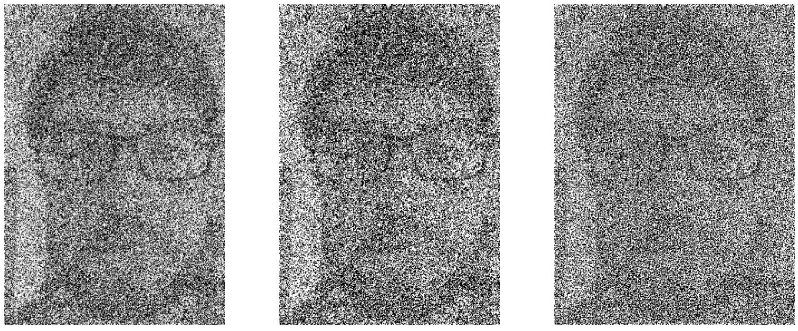
Figure 6: Thresholded Images after Gaussian Noise (0.001 Variance)

(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 0.01, the global threshold output provides good separation of the background and foreground, with good segmentation of the facial features.

At a variance value of 0.1, there is less separation of the foreground and background, however, the facial features are still visible.

The final tested noise variance is a value of 1, at which point the global and adaptive thresholds provide similar levels of separation.

1.5 Conclusion

Inspection of the workspace following this section shows the data types and dimensions of the structures used.

The workspace of part a shows the reduction of the dimensions from the input image to the greyscale image. The removal of the three channels representing RGB colour allows for much faster computations, due to a reduction in data to be processed.

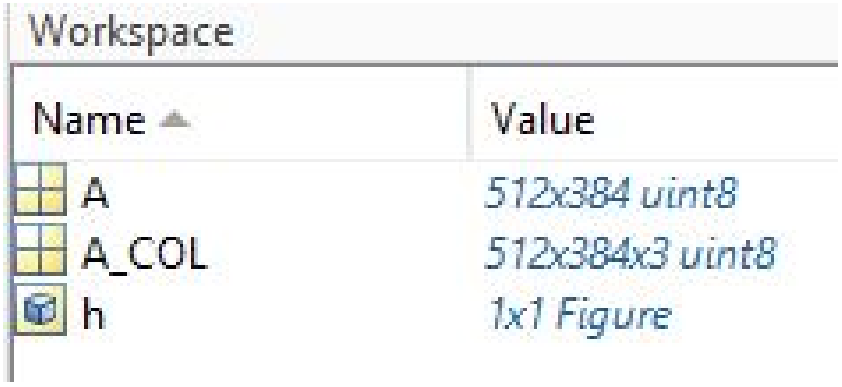


Figure 10: Part a Workspace

The workspace of part b shows the dimensions of the images, following the threshold function. The images are of the same dimension as the input image, however their values are stored as type “double” rather than integer.

The “data driven” threshold value can be seen as being calculated as 199. This threshold value, when applied to the image, was determined to be suboptimal. As such, alternative values for the threshold value were tested, with the optimal choice being 125.

Choosing the optimal threshold value for a global threshold function is difficult for a number of reasons, namely uneven lighting conditions, and, in the case of the input images, irregular surfaces such as glasses and facial hair. These features cause the shadowing on the left side of the image, the streak covering

the left eye (a shine on the glasses), and the blurring surrounding the lips.

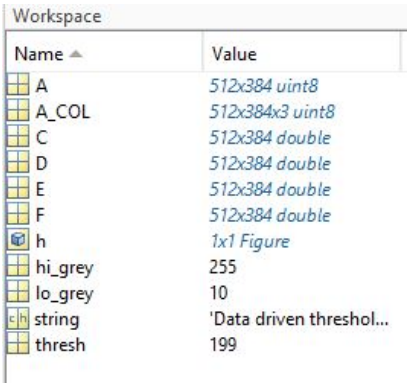


Figure 11: Part b Workspace

The final workspace of the 5x5 Adaptive Threshold show the dimensions of the output image, which are the same as the input greyscale image, and of type "double".

The 5x5 adaptive threshold, thresholding each pixel based on the average of the surrounding 5x5 region, provides adequate segmentation of the background and foreground. It also deals with issues such as uneven lighting conditions, glasses and reflections, and facial hair, with a better accuracy than the global threshold. The resulting image has better segmentation of the facial features, and better separation of the foreground and background.

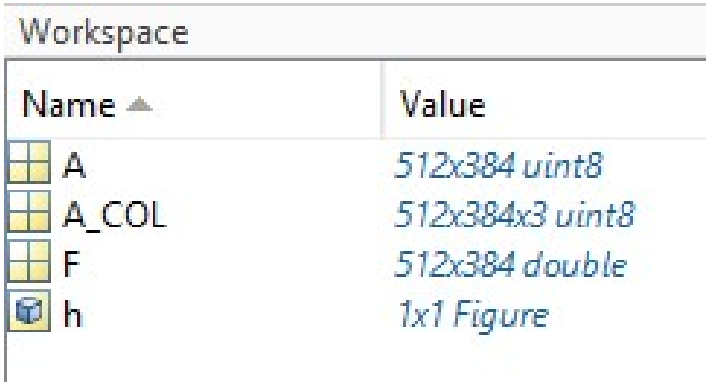


Figure 12: Part c Workspace

The final workspace of part d shows the resulting dimensions of both the adaptive and global threshold functions, as applied to the noisy input greyscale image.

From the results section above, it is clear that the global threshold technique is less sensitive to noise. As there is no weight placed on the pixel intensity values

within the image, there is less variance to the thresholding with the amount of noise found in the image.

As the adaptive thresholding relies strongly on the intensity values in the pixels surrounding the pixel in question, noise can have a greater effect on the thresholding.

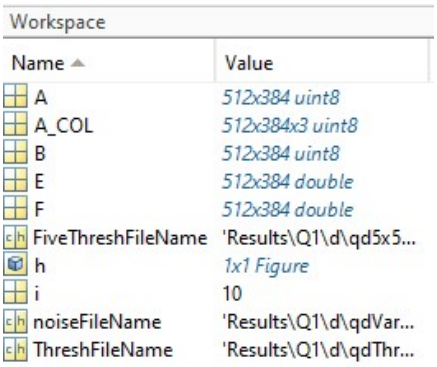


Figure 13: Part d Workspace

The code utilised in the completion of this section can be found in the Appendices.

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

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

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 14: 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 15: Preparing for Border Removal

(a) Biggest Blob (b) Biggest Blob Removed

Figure 16: 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 17: Removed Largest Alphanumeric Character

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

Figure 18: Characters Extracted from Loops 1-3

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

Figure 19: Characters Extracted from Loops 4-6

(a) Canny Edge Detection (b) Overlayed Images

Figure 20: 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

In order to test that the robustness of this code, a unit test file (q2pbtest.m) is executed. An assertion within the unit test checks the licence plate image against it's expected resulting number of characters, while passing a variance value to the "imnoise" function.

The point at which the solution fails is with a variance value of 6. At this point, enough noise is added that the border blob which is extracted is split, leaving a blob which is then mistakenly extracted as a character in the registration. As such, the unit test fails, with an output value of (in the below case) 8 not matching the correct value of 7.

(a) Zero Noise Overlay (b) Noise (with Variance 6) Overlay

Figure 21: Overlayed Characters

2.5 Conclusion

The final workspace shows the input image format, dimensions 328×1393. This RGB image is converted to greyscale, removing the three channels for the colourspace.

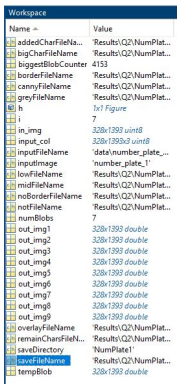


Figure 22: Part a Workspace

There are a number of intermediate values, of the same dimensions as the input image, used for the intermediate processing steps required in extracting the registration characters.

These intermediate steps include the low pass filtering, thresholding, inversion, and biggest blob removal. The looping of biggest blob removal, and addition to the output image is also stored in one of these intermediate values.

The chosen solution of looping through the biggest blobs until a certain ratio is reached allows for the robustness of this solution. An initial tested solution used the smallest blob in order to extract the characters, however, adding noise to the image increases the time taken to complete the task beyond the point of being usable.

The code utilised in the completion of this section, along with the output images from each example, can be found within the Appendices.

3 Part 3: Convolution

3.1 Introduction

Convolution is a common practice for pattern matching between an input image and a template image. In this section, a patterned input image, consisting of approximately 28 occurrences (full or partial) of the given template image, must have the number of full occurrences calculated.

Greyscale convolution between the input image and the template must return the number of fully visible pattern matches (i.e. matches with features not in contact with the borders), in a way which us both robust, and data drive. By using dilation, the features touching the border can be removed, and the following features can be highlighted using a combination of centroid, point to square, and overlaying techniques.

3.2 Techniques

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

3.2.1 Part a

Convolution

Convolution is a template matching technique. A template mask is compared across an input image. A strong match between the template image and the input image is represented by a greater intensity value. The VSG "Convolution" function takes an input image and template, and returns an image, of type double, with the same dimensions as the input image.

Rotate

Rotation is required both for testing the robustness of a solution, and for better template matching with respect to convolution. The VSG "RotateImg" function rotates an input image by an input angle.

Centroid

The centroid of an object is its center of gravity. This can be used within image processing for labelling purposes. The VSG "Centroid" function places a single white pixel at the "center of gravity" of the white blobs within the image. The

output of this function is an image of the same dimensions as the input image, with single white pixels (of value 255), surrounded by black pixels (of value 0).

Point to Square

In order to more easily represent a functions output, points can be converted to larger, more visible features. The VSG "Point2Square" function places a 5x5 square surrounding any single pixels of intensity value 255.

3.2.2 Part b

Reconstruction By Dilation

Reconstruction by dilation is a technique which can be used to detect features in contact with the image border. Passing the input image into the VSG "ReconByDil" function, along with the border pixels of the image, the features in contact with the border can be reconstructed, and subsequently removed from the image.

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" function.
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 "ReconByDil" function to remove 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.

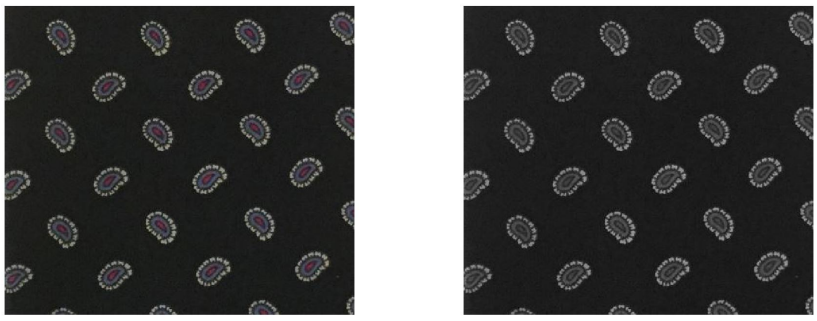
3.3.3 Part c

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

In part a, the greyscale convolution is executed correctly, resulting in the highlighting of the matching patterns within the image. The input image is first correctly loaded into Matlab, and converted to greyscale.



(a) Input Image (b) Input Greyscale Image

Figure 23: Input image and Greyscale Conversion

The template image is then loaded into Matlab, and is also converted to greyscale. In order to make the pattern matching more robust, a copy of the greyscale input is stored.

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

Figure 24: Required Template for Convolution

The convolution function is applied to the input image with both the template, and rotated template images. The highlighted regions within the image is returned from the convolution function, and the two outputs are combined using the VSG "Add" function.

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

Figure 25: Convolution outputs: Original Template(OT), Rotated Template(RT), Added Results(+)

A data driven threshold, much like that used in section 1 is applied to the convolution output. This results in a number of blobs, of intensity value 255, which can then be converted to points using the "Centroid" function. These points can be represented as squares for visualization purposes, using the "Point2Square" function.

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

Figure 26: Outputs from the "Threshold", "Centroid", and "Point2Square" Functions, showing the locations of template matches

The squares representing the positions of pattern matches can be overlayed on the original image, using the VSG "Add" function.

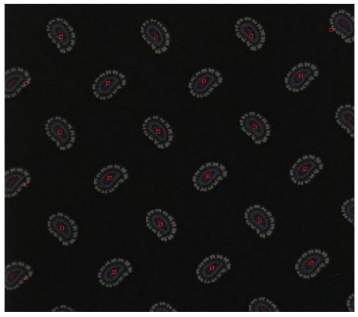
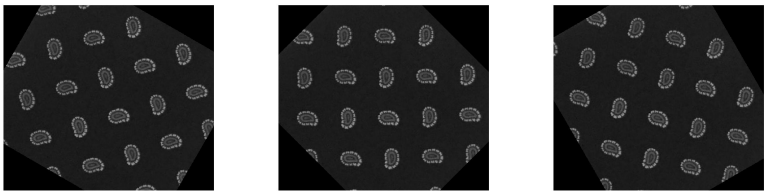


Figure 27: Overlay showing Location of Pattern Matches

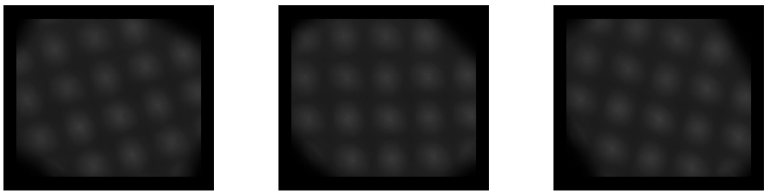
In order to investigate the effects of rotating the input image, the greyscale input image is rotated by 30, 45, and 60 degrees.



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

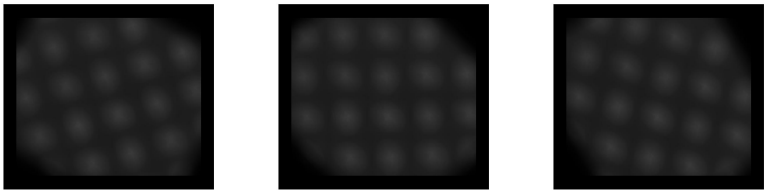
Figure 28: Input Image Rotated 30°, 45° & 60°

Applying convolution with the two template images results in the following images.



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

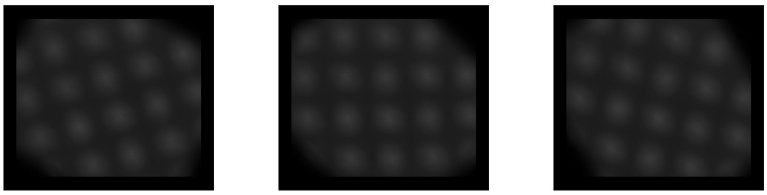
Figure 29: Convolution with Template: $30°, 45°$ & $60°$



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

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

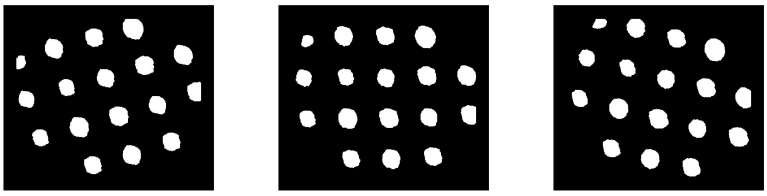
Adding the results of the convolutions results in the following images.



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

Figure 31: Added Convolution Results: $30°, 45°$ & $60°$

Thresholding each of the convolution outputs returns a number of blobs, as in the original image, rotated by the input angle.



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

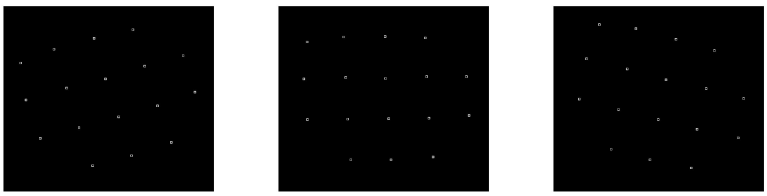
Figure 32: Threshold: $30°, 45°$ & $60°$

The centroid of each blob in the resulting threshold image is shown below, with a single white pixel of intensity 255 representing the "center of gravity" of the blob.

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

Figure 33: Centroid: $30°, 45°$ & $60°$

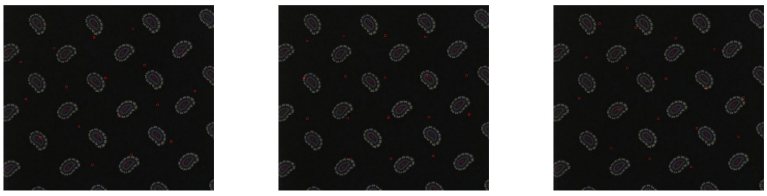
As before, the "Point2Square" function is used for visualisation purposes.



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

Figure 34: Point2Square: $30°, 45°$ & $60°$

The overlay images show the offset between the original input image (not rotated), and the template matches (rotated).



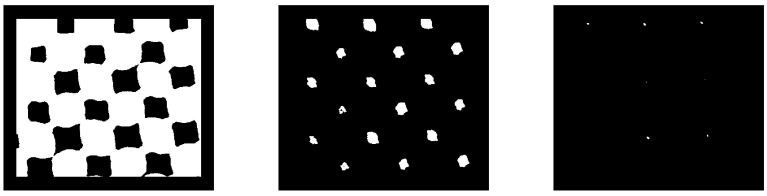
(a) Overlay 30° (b) Overlay 45° (c) Overlay 60∘

Figure 35: Overlay: $30°, 45°$ & $60°$

In order to evaluate the effects of varying the threshold value on the template matching, threshold functions of different values are applied to the convolution output. As can be seen, a lower threshold value of 32 results in a single blob, which would return a single centroid point and match.

A threshold value of 50 results in a number of smaller unconnected blobs, which can give incorrect output values.

A threshold value of 60 results in fewer blobs, therefore giving fewer centroids, and, again, incorrect output values.



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

Figure 36: Convolution Thresholded at Values: 32, 50, & 60

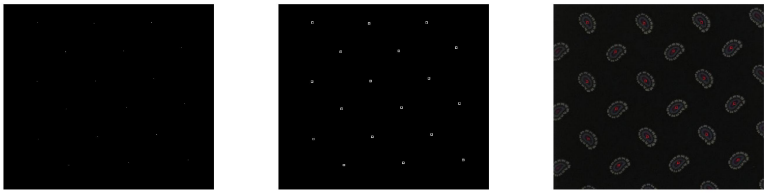
3.4.2 Part b

In part b, the edge connected features are removed from the image using the VSG "ReconByDil" function, which, when given an input of the original images border pixels can "regrow" the connected features. These features can then be removed from the input image.

The resulting image can then be processed as in part a.

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

Figure 37: Dilation, Convolution and Thresholding Applied to Input Image



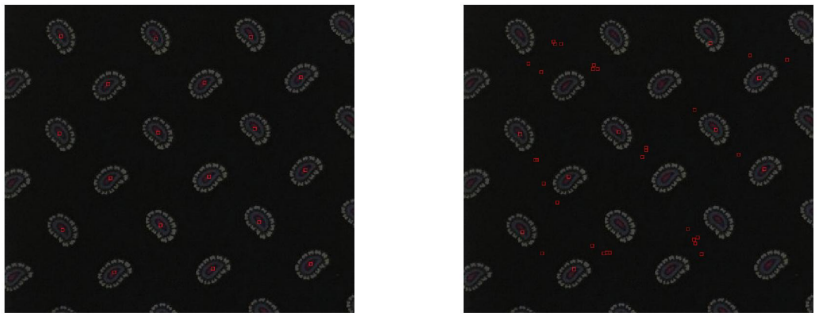
(a) Centroid (b) Point2Square (c) Overlay

Figure 38: Overlay of Template Match on Original Input Image

As visible in the above overlay image, the correct count of 18 pattern matches is achieved.

3.4.3 Part c

Part c investigates the robustness of the chosen solution. Incrementing the noise variance shows that the incorrect pattern match count is achieved at a variance of 0.1, while the solution can deal with noise up to an approximate variance of 0.01.



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

Figure 39: Overlay showing correct template matching at 0.01 variance, and incorrect matching at 0.1 variance.

3.5 Conclusion

The final workspace of part a shows the dimensions of the input RGB image ($406 \times 461 \times 3$), the input RGB mask ($60 \times 57 \times 3$), and any intermediate values.

The greyscale input and mask images have the same dimensions as the input images, however they do not have the channels for the colourspace.

The final output image has all pattern matches, which includes some incorrect matches due to the edge connected features, stored in an RGB space, where the intensities of the squares used to represent the pattern matches are added to the red channel of the original input image.

Workspace

Name	Value
h	*1x1 Figure*
hi_grey	63
in_col	*406x461x3 uint8*
in_img	*406x461 uint8*
lo_grey	0
mask	*60x57 uint8*
mask_col	*60x57x3 uint8*
mask_rot	*60x57 double*
out_img1	*406x461 double*
out_img2	*406x461 double*
out_img3	*406x461 double*
out_img4	*406x461 double*
out_img5	*406x461 double*
out_img6	*406x461x3 double*
thresh	47

Figure 40: Part a Workspace

The final workspace of part b shows the same values as in part a, alongside the "numPatterns" value, output from the "WPCounter" function. This function counts the number of white pixels following the "Centroid" function, which

corresponds to the number of pattern matches in the image.

As is required in the specification, there are 18 pattern matches found in the image.

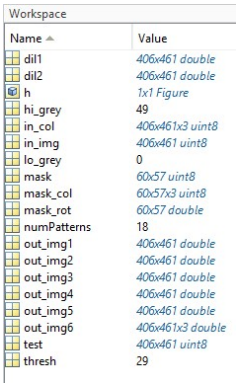


Figure 41: Part b Workspace

The final workspace of part c shows the same values as in part b, with the newly completed dilation function output, and an incorrect output value for the number of pattern matches.

As the noise applied to the input image is increased, the dilation begins to encroach further into the image than it should, affecting the pattern matches from the convolution function, which in turn affects the thresholding function. As such, adding noise to the image eventually results in an incorrect number of pattern matches.

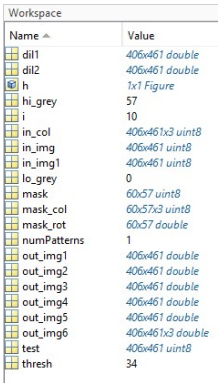


Figure 42: Part c Workspace

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:

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

Figure 43: Initial Segmentation Setup

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

Figure 44: Preparing for Border Removal

(a) Biggest Blob (b) Biggest Blob Removed

Figure 45: Removed Outer Border

(a) Largest Character (b) Remaining Characters

Figure 46: Removed Largest Alphanumeric Character

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

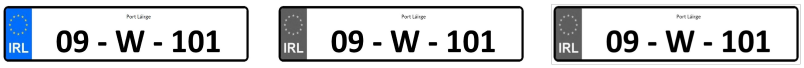
Figure 47: Characters Extracted from Loops 1-3

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

Figure 48: Characters Extracted from Loops 4-6

(a) Canny Edge Detection (b) Overlayed Images

Figure 49: Overlayed Extracted Characters



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

Figure 50: Initial Segmentation Setup

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

Figure 51: Preparing for Border Removal

(a) Biggest Blob (b) Biggest Blob Removed

Figure 52: Removed Outer Border

(a) Largest Character (b) Remaining Characters

Figure 53: Removed Largest Alphanumeric Character

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

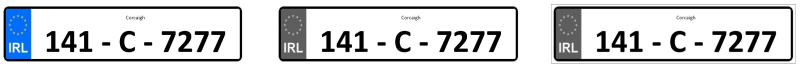
Figure 54: Characters Extracted from Loops 1-3

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

Figure 55: Characters Extracted from Loops 4-5

(a) Canny Edge Detection (b) Overlayed Images

Figure 56: Overlayed Extracted Characters



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

Figure 57: Initial Segmentation Setup

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

Figure 58: Preparing for Border Removal

(a) Biggest Blob (b) Biggest Blob Removed

Figure 59: Removed Outer Border

(a) Largest Character (b) Remaining Characters

Figure 60: Removed Largest Alphanumeric Character

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

Figure 61: Characters Extracted from Loops 1-3

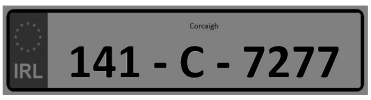
(a) Loop 4 Result

(b) Loop 5 Result

(c) Loop 6 Result

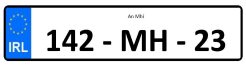
Figure 62: Characters Extracted from Loops 4-6

(a) Canny Edge Detection

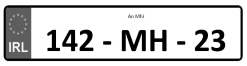


(b) Overlayed Images

Figure 63: Overlayed Extracted Characters



(a) Input Image



(b) Greyscale Image

(c) Low Pass Filtered

Figure 64: Initial Segmentation Setup

(a) Mid Threshold

(b) Inverted (Not)

Figure 65: Preparing for Border Removal

(a) Biggest Blob

(b) Biggest Blob Removed

Figure 66: Removed Outer Border

(a) Largest Character

(b) Remaining Characters

Figure 67: Removed Largest Alphanumeric Character

(a) Loop 1 Result

(b) Loop 2 Result

(c) Loop 3 Result

Figure 68: Characters Extracted from Loops 1-3

(a) Loop 4 Result

(b) Loop 5 Result

(c) Loop 6 Result

Figure 69: Characters Extracted from Loops 4-6

(a) Canny Edge Detection

(b) Overlayed Images

Figure 70: Overlayed Extracted Characters

(a) Input Image

(b) Greyscale Image

(c) Low Pass Filtered

Figure 71: Initial Segmentation Setup

(a) Mid Threshold

(b) Inverted (Not)

Figure 72: Preparing for Border Removal

(a) Biggest Blob

(b) Biggest Blob Removed

Figure 73: Removed Outer Border

(a) Largest Character

(b) Remaining Characters

Figure 74: Removed Largest Alphanumeric Character

(a) Loop 1 Result

(b) Loop 2 Result

(c) Loop 3 Result

Figure 75: Characters Extracted from Loops 1-3

(a) Loop 4 Result

(b) Loop 5 Result

(c) Loop 6 Result

Figure 76: Characters Extracted from Loops 4-6

(a) Canny Edge Detection

(b) Overlayed Images

Figure 77: Overlayed Extracted Characters

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;
```