VEHICLE LOCATOR SYSTEM FOR MULTI-STORAGE CAR PARK MANAGEMENT

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"In the Name of Allah, The Most Beneficent, The Most Merciful"

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ABSTRACT

Automatic recognition of car license plate number became a very important in our daily life because of the unlimited increase of cars and transportation systems, thus it is impossible to manage and monitored by humans manually. Unable to locate parked car always become main problem especially in huge car parking system. Many researchers suggest and employ plate recognition system (which is usually called as Automatic Number Plate Recognition (ANPR)) in order to recognise car. There are a number of different techniques which have been used for recognition of registration plate characters due to the diversity of plate formats, different scales, rotations and non-uniform illumination conditions during image acquisition. Malaysia also has different types of plate number. The development of the ANPR system is still lacking and most of the time they just plug and play of ANPR engine without further evaluation and analysis. Hence, the main aim of this project is to develop ANPR system for common Malaysian plate styles with comprehensive evaluations. Four main objectives of this study which is i) to collect, gather and acquire images of cars in parking, ii) to design ANPR system for Malaysian plate styles, iii) to evaluate the performance of the developed ANPR system, and iv) to develop Graphical User Interface (GUI) for ANPR system to ease of use. The system is developed using three stages of processing: i) plate extraction - identify plate regions, ii) character segmentation - one-by-one character detection and isolation, and iii) character recognition - character matching process. The experimental results show that the system is able to recognise plate number by at least more than 80% of recognition accuracy and less than 1% segmentation errors. The system is ready to be used to detect the presence of cars in parking space.

ABSTRAK

Pengecaman nombor plat kereta secara automatik menjadi sangat penting dalam kehidupan seharian selari dengan meningkatnya jumlah kereta dan sistem pengangkutan yang lain dan ianya mustahil untuk diselia oleh manusia secara manual. Kehilangan kereta di tempat letak kereta menjadi masalah utama terutamanya di tempat letak kereta yang besar. Ramai penyelidik mencadangkan serta menggunakan sistem pengecaman plat (biasanya dikenali sebagai Pengecaman Nombor Plat Secara Automatik (ANPR)) untuk mengecam kereta. Terdapat beberapa teknik berbeza yang telah diguna untuk mengecam plat kerana kepelbagaian format plat, skala yang berbeza-beza, kedudukan plat, dan keadaan pencahayaan yang tidak seragam semasa imej diambil. Malaysia juga mempunyai nombor plat yang berlainan. Pembangunan sistem ANPR juga masih kurang dan kebanyakannya hanya menggunakan enjin ANPR sedia ada tanpa analisis lanjut dan menyeluruh. Oleh itu, matlamat utama projek ini adalah untuk membangunkan sistem ANPR untuk jenis plat Malaysia dengan penilaian yang mendalam. Empat objektif kajian ini ialah i) untuk mengumpul, memperoleh imej kereta di tempat letak kereta, ii) untuk membangunkan sistem ANPR untuk jenis plat Malaysia, iii) untuk menilai prestasi sistem ANPR yang dibangunkan, dan iv) untuk membangunkan Antara Muka Pengguna Grafik (GUI) bagi memudahkan penggunaan. Sistem ini dibangunkan menggunakan tiga peringkat pemprosesan: i) pengekstrakan plat - mengenal pasti kawasan plat, ii) segmentasi aksara - pengesanan dan pengasingan aksara satu demi satu, dan iii) pengecaman aksara - proses padanan aksara. Keputusan ujikaji menunjukkan bahawa sistem dapat mengecam nombor plat dengan sekurang-kurangnya lebih daripada 80% ketepatan pengecaman dan kurang daripada 1% kesilapan segmentasi. Sistem ini telah sedia digunakan untuk mengesan kehadiran kereta di ruang letak kereta.

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LIST OF ABBREVIATIONS

ALPR	Automatic License Plate Recognition
ANPR	Automatic Number Plate Recognition
FKMP	Fakulti Kejuruteraan Mekanikal & Pembuatan
FN	False Negative
FP	False Positive
GTI	Ground Truth Image
ITS	Intelligent Transport System
LPR	License Plate Recognition
MAA	Malaysia Automotive Association
MATLAB	MATrix LABoratory
OCR	Optical Character Recognition
SE	Structuring Element
SI	Segmented Image
TP	True Positive
TN	True Negative

CHAPTER 1: INTRODUCTION

1.1 RESEARCH BACKGROUND

Nowadays, transportation has become one of the important factors which contribute to the growth of a country. Transportation is responsible to move people from one place to another without requiring less effort and energy. Without transportation, it will require human to take hours or days to reach desired destination. Human using the transportation to export or import raw materials to other countries. There are a lot of different kinds of transportation nowadays such as vehicle, airplane and etc.

Usually, vehicle such as car really dominate the transportation industries as it is more convenience to use. Normally, vehicles need to be parked at their specific places such as a shopping mall, offices and apartment. One of the problems that have been faced by the owner of the car is regarding their car safety in the parking lot.

According to the Malaysia Automotive Association (MAA) data up to June 2017, the total number of vehicles on roads keeping the standing score of more 13,288,797 units. The human can not control by manually this massive number of vehicle There is a need to improve the current system that could tailor easier and faster sensor track management of vehicle information especially at high-traffic and restricted areas such as border control point, restricted car park or vehicle storage areas, high-speed traffic and toll gate access.

Hence the development of the Automatic Number Plate Recognition which is usually abbreviated as ANPR has attracted worldwide attention from many fields of researcher especially automotive industry. This system can be used to find and record their car location or even captured the criminal. Basically, car plate or vehicle registration plate is a plate that will be attached at the front or the back of the car. The plate is made of either plastic or metal. Car plate numbers are crucial in representing the identity of the car. It contains a set of numbers and letters that will be assigned to their respective district or country. The first or early design of license plate in United Kingdom are being applied here also in Malaysia [1]. Based on the car's license plate, from the first letter, we can know from where the car location originally and followed by random four numbers or specially custom order number that will require more cost.

ANPR is a tracking system that identifies the vehicle so that the car is traced down based on stored plate number in the database. Usually this system will be put at the gate of a parking lot, electronic tolls, entrance of an education campus or in other high-secured building. This tracking system will recognize the vehicle automatically by focusing on the target car plate which may be involved in a violation of traffic, crimes or maybe the car itself has been reported as stolen vehicles.

1.2 PROBLEM STATEMENT

ANPR is a system especially the one related to the vehicle number plate recognition system. The system is developed to ease the recognition of the vehicle number plate, especially around the crowded places and roads. Nowadays, the total vehicle number on roads in Malaysia has been significantly increasing, and current traffic on roads makes the law enforcement especially in monitoring the security of the vehicle, and the car parks become much complicated.

The vehicle number plate especially in most developing country used a standardised monitoring system that involves similar monitoring information including the types of the letter and plate size. The main advantage of the standardisation of vehicle number plate system is to ease the system to recognise the number plate. However, the main disadvantage of ANPR system is to standardise between all countries since each country has different types of plate number. For example, in the United Kingdom the standard type of vehicle is using yellow color with black numbering and characters meanwhile United States of America uses multiple color background as well as numbering characters for their plates. Therefore, they developed a different ANPR engine to suit their needs.

This problem was highlighted by [2] which stated one problem that usually occurs is that one algorithm cannot be globally used as different countries have different style of number plates Some countries used their own language to represent the English alphabets and numbers for their car plates. As a result, these countries have to develop their own automatic recognition system as the existing system cannot be used [1].

Malaysia also has different types of plate. The development of the system is still lacking and most of the time they just plug and play of ANPR engine without further evaluation and analysis. Hence, the main aim of this project is to develop ANPR system for Malaysian plate styles with comprehensive evaluations.

1.3 RESEARCH OBJECTIVES

i. To collect, gather and acquire images of cars in parking;
ii. To design Automatic Number Plate Recognition system for Malaysian plate styles;
iii. To evaluate the performance of the developed ANPR system;
iv. To develop Graphical User Interface (GUI) for ANPR system to ease of use.

1.4 RESEARCH SCOPES

In general, the scope of the research has been specified as studying and developing ANPR system using MATLAB. A car plate is specified to standard car plate in Malaysia. In addition, this system can have an ability to process both single line and two lines type of car plate. Colour of the cars, distance of the car from the camera, shape, front facing or back are some of the variables that can affect the results of this project, therefore all of these parameters are considered as further evaluations of the developed system. Collecting, gathering and capturing varieties of car in parking lot are also the main priority in this project. Most of the data are captured around Fakulti Kejuruteraan Mekanikal & Pembuatan (FKMP) and the camera used for taking all the images is by using a common smartphone camera.

CHAPTER 2: LITERATURE REVIEW

2.1 MALAYSIAN STYLES PLATE NUMBER

Commonly, there are various categories of automobiles such as motor, car etc. For identification purpose, license plate number need to follow all the criteria or rules that have been set by the government. There are two kinds of car number plate in Malaysia. For personal car, the plate number contains white font colour and black background colour while for taxi it is vice versa. The background colour and font colour of the taxi license plate is the complete opposite of personal car [3]. Another variation of vehicle number plates is that it has one or two lines. All of vehicle license plates in Malaysia need to abide the rule that has been set by JPJ as shown in Figure 2.1. Figure 2.2 shows various plate number in Malaysia.

Figure 2.1: Standard plate size from JPJ [4]

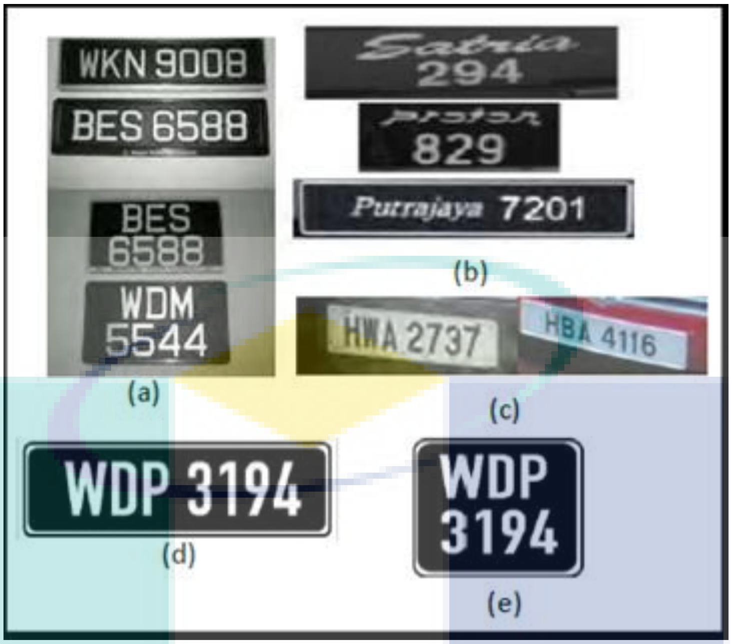


Figure 2.2: (a) Malaysia license plates (b) Special license plates (c) License plates for taxi (d) Single row license plates (e) Double row line licenses plate [3]

2.2 BASIC ANPR SYSTEM

System that monitors the license plate of a car can be defined in many terms such as Automatic Number Plate Recognition (ANPR), License Plate Recognition (LPR) and Automatic License Plate Recognition (ALPR). ANPR is considered an Intelligent Transport System (ITS) technology that can distinguishes and counts the quantity of vehicles [5]. ANPR is an image processing technology used to locate vehicles by their license plates [6]. ITS is a real-time, accurate, and efficient transportation management system can solve the various road problems generated by the traffic congestion, thus receiving more and more attention [2]. Various recognition techniques have been developed and ANPR systems are being used nowadays in various traffic and security applications, such as parking, access and border control, or tracking of stolen cars [7].

ANPR system generally consists of three concrete phase namely: i) plate region extraction, ii) character segmentation and iii) character recognition [8][9]. Some literatures included pre-processing together with plate region extraction stage. Figure 2.3 splits these two processes as two main processes, however it gives the same interpretation and meaning from the author point of view.

At the first stage, ANPR method will verify the position of number plate from the captured image. Plate extraction is a function that locates the position of the plate, determines the aspect of image vehicle whether the plate is in front or back of the vehicle. For example, the number plate detection can look for geometric shapes of rectangular proportion by using algorithm. In general, the algorithm can detect the characteristics of the vehicle number plate image that would then indicate the object, background colour of unified proportion contrast and brightness, number plate sizing and orientation, and differentiate object vehicle by the algorithm. In this case, three methods are usually used which are edge-based detection, texture based detection and colour grayscale in the image. The second step is the character segmentation processing stage which is act as a function to separate the alphanumeric characters on vehicle number plate. All type of number plate characters can be distinguished based on the sequence output. In this case, the algorithm would divide each of the letter or number and subsequently passed to character recognition. Basically, combination of character segmentation and character recognition stages are also called Optical Character Recognition (OCR). The primary function of OCR is to capture image into an alphanumeric text. The segmented character from the previous phase are then matched with character images from the database. The similarity can be obtained through the characters with similar colour or equidistance. This process is known as database template matching.

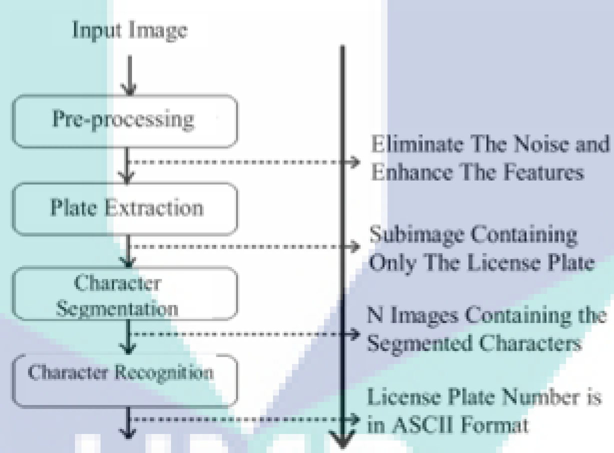


Figure 2.3: Basic flowchart of ANPR system [9]

2.2.1 Plate Extraction Techniques

For the past few years, many studies have been done on various techniques for plate extraction involving the two-method process that is known as colour edge contrast and accurate edge detection [10]. The approach for edge detection used the edge images of the vehicles. The character with height and spacing defined the structural elements that are pixel horizontally and vertically. The digits and characters contain many vertical edges. The high colour contrast (white lettering on black background) will lead to more visual variation, especially in night field test. The two methods have a disadvantage for example an edge detection is background interference create the high magnitude of edges.

For colour contrast method which is implemented in [11], the upper half of the image is eliminated and the number plate image is at the bottom half of the image. By comparing the pixels of the image through horizontal and vertical edges, the summation of the differences within the column and row is figured out. The signal smoothing went through the filter which eliminates the underlying signals that are less than the actual average signal. Therefore, the highest contrast area is then considered as the number plate area.

As reviewed by [12] the method used to detect the number plate involved detection algorithm method that employs mathematical morphology dilation operation. Dilation operation will produce more significant size object, due to the exchange of pixel value with the maximum value for the size test of the 3x3 window around the pixel. The pixels addition to the boundaries of objects helps to create significant effects. The number of size and shape of structuring element determines the whole element that must be added to the processed image. Prior to character segmentation, preprocessing and object enhancement algorithm needs to be done such as converting to grayscale and binarisation (image thresholding).

2.2.2 Character Segmentation Techniques

Character segmentation phase uses the dilation image to segments all the characters without ignoring all the segments character. In this phase, the character and digits of the vehicle number plate are segmented, and each of them is saved as different images. The image region properties are measured using the bounding box and returned the smallest bounding box that contains a character. This method is used in [13][14] to get the all character in image number plate using the bounding boxes. This step permits the extraction of the plate number based on the labelling component and then separated and split into the character which is then compared to the database in the form of range integer and character values between 0 to 9 and A to Z, respectively. The database are then converts the value to a string [10].

2.2.3 Character Recognition Techniques

Comparing the image and a set of reference image similarity is what defined as template matching [15]. The techniques will cross reference both of the data and show the one that has the most similarity. It will calculate how well the template set matches the image and will try all the possible position in the image. The character recognition uses template matching in recognising the characters which have been reported previously in several studies such as in [16-19]. The matching is using the statistical correlation method to compare the character with database (Figure 2.4) and returned the ranked best similarity metrics.

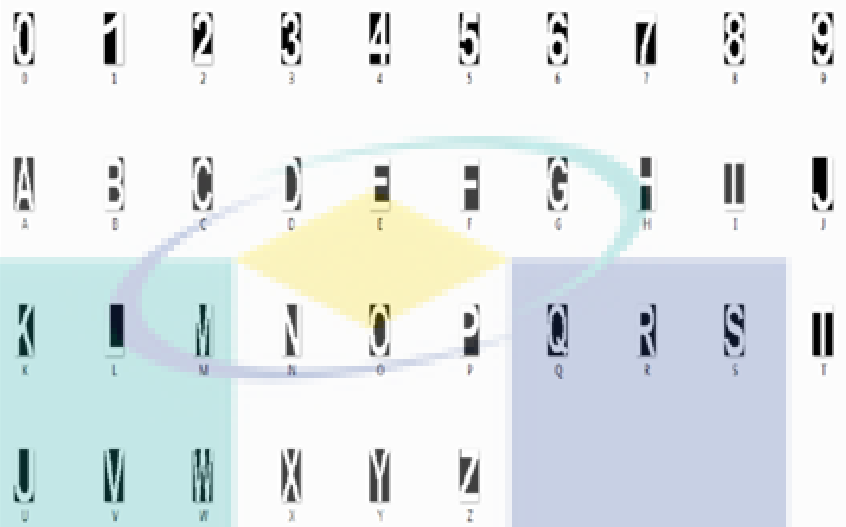


Figure 2.4: Templates used for template matching [15]

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

Figure 3.1 shows the flowchart of the research.

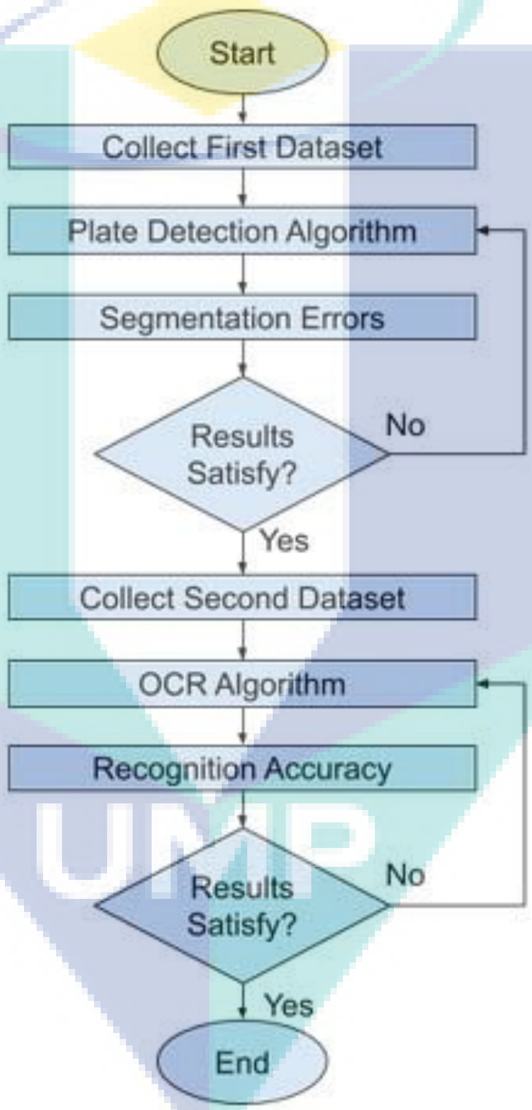


Figure 3.1: The research flowchart

All of the processes are explained in the following subtopics.

3.2 IMAGE DATASET

In order to obtain realistic experimental results, the research needs the real Malaysian vehicle license plate image. As mentioned before, due to research constraint, the algorithm for plate extraction and OCR is tested separately, therefore two set of dataset is needed. For first dataset, the image is taken with the absent of vehicle body as illustrated in Figure 3.2. A total of 50 images are taken for the first dataset and all of the images can be viewed in APPENDIX A1.

Figure 3.2: The image sample for first dataset

In the second dataset, the images of car's plate are taken as close as possible to the plate. The sample of the image is as shown in Figure 3.3 and other 50 images can be referred to APPENDIX B1.

Figure 3.3: The image sample for second dataset

3.3 PLATE DETECTION ALGORITHM

The next sub-topic explains the methods used to develop plate detection algorithm. The developed algorithm is based on [20] and supported by MATLAB image processing library.

3.3.1 RGB to Grayscale Conversion

Since the developed plate detection algorithm are using edge detection method, color information will be discarded at the first stage. The formula for standard RGB to grayscale is as follows:

$$Grayscale = (0.299 \times R) + (0.587 \times G) + (0.114 \times B) \quad \text{Eq. 3.1}$$

where, *R*, *G*, and *B* represents Red, Green, and Blue respectively.

3.3.2 Image Filtering

For this implementation, Sobel filter is selected since it is widely used in this area. Sobel filter is the process that is used to locate the boundaries of objects or textures depicted in an image. There are two types of Sobel filter which is vertical and horizontal. Usually license plate contain characters that have more vertical edges [20]. Hence the vertical Sobel filter is applied here using vertical masking. In the edge function, the Sobel method uses the derivative approximation to find edges of the image. The operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives – one for horizontal changes, and one for vertical. Figure 3.4 shows the 3x3 kernels for Sobel filtering.

+1	0	-1
+2	0	-2
+1	0	-1

(a)

+1	+2	+1
0	0	0
-1	-2	-1

(b)

Figure 3.4: The operator of Sobel, (a) horizontal and (b) vertical

3.3.3 Image Normalization

Normalization is implemented for adjusting the brightness and contrast (intensity value) of the image. The purpose of normalization is usually to bring the image, or other type of signal, into a range that is more familiar or normal to the senses. Here the normalization is used to remove the empty white space form the characters. Let's n-dimensional grayscale (*I*), with intensity values in the range (*Min*,*Max*), into a new image (*newMin*,*newMax*) The linear normalization of a grayscale digital image is performed and new intensity value (I_N) is calculated according to the following formula:

$$I_N = (I - Min)\frac{newMax - newMin}{Max - Min} + newMin \qquad \text{Eq. 3.2}$$

3.3.4 Image Thresholding

Two stages of image thresholding is implemented by using Otsu's method and followed histogram equalization. Otsu's method is the simplest form whereby the algorithm returns a single intensity threshold that separate pixels into two classes, foreground and background. This threshold is determined by minimizing intra-class intensity variance, or equivalently, by maximizing inter-class variance. On the other hand, histogram equalization is a method in image processing of contrast adjustment using the image's histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

3.3.5 Vertical Mask Filtering

Based on the histogram analysis, the most probable candidate region will be selected. To remove the thin lines which are not part of the license plate, once again vertical masking is used using Sobel operator.

3.3.6 Morphological Processing

Morphological image processing has been used widely to enhance the binary image. It is a collection of non-linear operations related to the shape or morphology of features in an image. This techniques probe an image with a small shape or template called a structuring element (SE). The SE is positioned at all locations in the image and it is compared with the corresponding neighborhood of pixels. The operations test whether the element "fits" within the neighborhood or it "hits" and intersects the neighborhood.

The erosion of a binary image *f* by a SE *s* (denoted $f \ominus s$) produces a new binary image $g = f \ominus s$ with ones in all locations (x, y) of a structuring element's origin at which that SE, *s* "fits" the input image f. For example, $g(x, y) = 1$ is *s* "fits" *f* and 0 otherwise, repeating for all pixel coordinates (x, y). The dilation of a binary image f by a SE s (denoted $f \oplus s$) produces a new binary image $g = f \oplus s$ with ones in all locations (x, y) of a structuring element's origin at which that SE s "hits" the input image *f*. For example, $g(x, y) = 1$ if s "hits" f and 0 otherwise, repeating for all pixel coordinates (x, y). Dilation operation has the opposite effect to erosion whereby it adds a layer of pixels to both the inner and outer boundaries of regions.

Two basic operators of morphology are dilation and erosion. It is typically functional on binary images and to grayscale images. On binary image, the boundary of the area of foreground are enlarge when used dilation. So it will grow in size while retaining the holes small. In this algorithm, the image is dilated vertically and horizontally using disk SE.

After vertical and horizontal dilation has been completed, both output is then joined. Horizontal dilation will once again be apply on the joined image. After that, the erosion process will be carried out. Basically, the erosion is responsible to eliminate area that do not belong to the plate.

3.3.7 Detected Plate Region

There are a few possible plate regions detected at the previous stage. At the final stage, the biggest area of detected regions are considered as plate region and then being marked and cropped to be ready for character matching stage.

3.4 OCR ALGORITHM

The first step in this algorithm is to convert original RGB image into a grayscale image. Secondly, the image is then segmented to isolate background and foreground (the characters). Then, the binary image is being smooth using morphological image processing. As usual, erosion and dilation processes are being selected using disk SE.

The bounding box algorithm is implemented in the next phase to remove unwanted plate region. After that, each of the characters is separately cropped by finding the large range of box. Finally, each of found characters is matched with character template (Figure 3.5) using correlation formula.

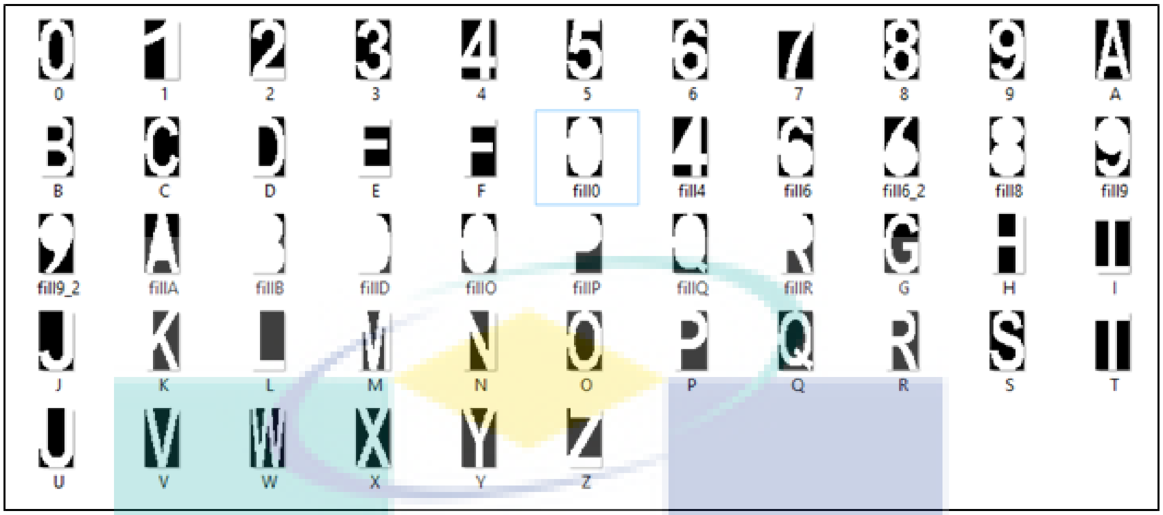


Figure 3.5: Character template in MATLAB

3.5 PERFORMANCE EVALUATIONS METRIC

There are two evaluations metric that are considered in the study which is segmentation errors and recognition accuracy.

3.5.1 Segmentation Errors

The principle behind segmentation errors method is by calculating the average correct and incorrect classified pixels occurred in segmented binary image (SI) compared to the real image. The real image will be considered as a "Ground Truth Image" (GTI) which refers to a set of measurements that is known to be much more accurate than measurements from the system you are testing in our cases manually cropped license plate region using MATLAB [21]. For an example from Figure 3.6, in common sense Figure 3.6 (c) will be having lower segmentation error to the naked eye as only two pixels are misclassified from the GTI image.

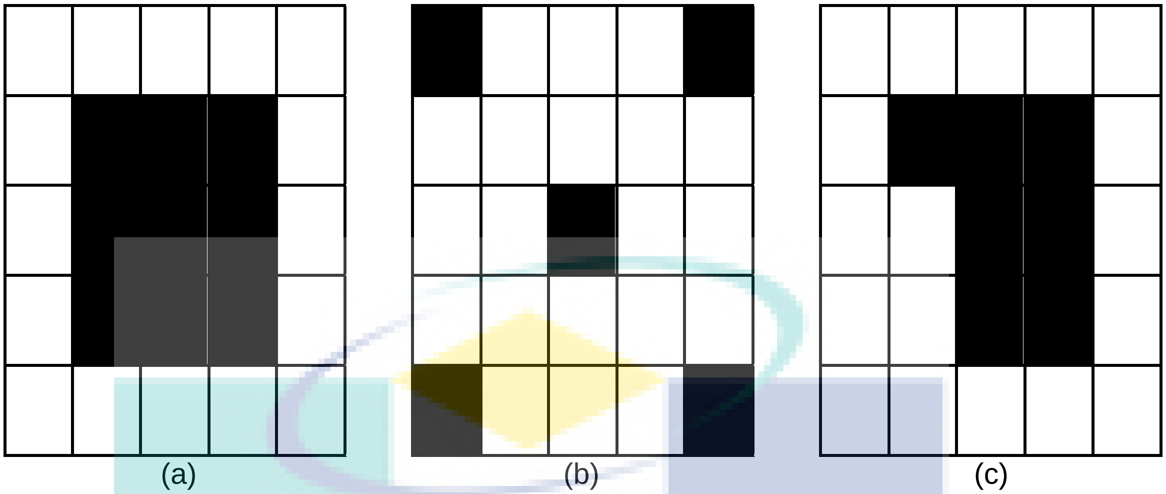


Figure 3.6: (a) GTI image (b) SI no. 1 (c) SI no. 2

This method was calculated by counting the False Positive (FP), False Negative (FN), True Positive (TP) and True Negative (TN). As our final image is in binary we can use this method to calculate the segmentation error using formula provided in Table 3.1. Both of the GTI and SI images will also be resize into the same size first before going further into calculating the segmentation error.

Table 3.1: Segmentation error calculations

Definition	**Denoted as**	**Formula**
Probability of each level	P(black)	$\frac{number\ of\ black\ pixel\ in\ GTI}{total\ number\ of\ all\ pixels\ in\ GTI}$
	P(white)	$\frac{number\ of\ white\ pixel\ in\ GTI}{total\ number\ of\ all\ pixels\ in\ GTI}$
False positive and negative	FP	$\frac{number\ of\ black\ pixel\ in\ GTI\ but\ white\ pixel\ in\ SI}{number\ of\ black\ pixels\ in\ GTI}$
	FN	$\frac{number\ of\ white\ pixel\ in\ GTI\ but\ black\ pixel\ in\ SI}{number\ of\ white\ pixels\ in\ GTI}$
True positive and negative	TP	$\frac{number\ of\ black\ pixel\ in\ GTI\ and\ black\ pixel\ in\ SI}{number\ of\ white\ pixels\ in\ GTI}$
	TN	$\frac{number\ of\ white\ pixel\ in\ GTI\ and\ white\ pixel\ in\ SI}{number\ of\ white\ pixels\ in\ GTI}$
Segmentation errors	SE	$\frac{FN + FP}{FN + FP\ TN + TP}$

3.5.2 Recognition Accuracy

The character detected are calculated based on confusion matrix (Table 3.2). Recognition accuracy is then calculated from the confusion matrix entries is:

$$Recognition\ Accuracy = \frac{(TN+TP)}{(TN+TP+FN+TP)} \times 100 \qquad \text{Eq. 3.3}$$

Table 3.2: Confusion matrix table also called contingency table

		Predicted	
		Character	Non-Character
Actual	Character	TN	FP
	Non-Character	FN	TP

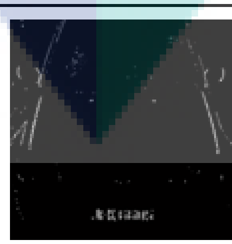
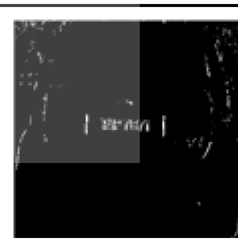
CHAPTER 4: RESULTS AND DISCUSSIONS

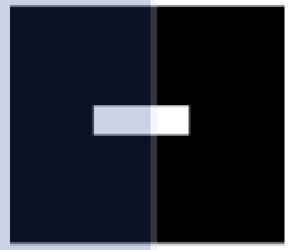
This chapter presents the output and results for the developed ANPR system as well as the results discussion. The layout of the chapter is starting with plate detection algorithm, OCR algorithm, and finally the GUI implementation.

4.1 IMAGE OUTPUT ON PLATE DETECTION ALGORITHM

Table 4.1 shows a step-by-step results output for each of the important stages in plate detection algorithm on two image samples. The output for all images can be viewed in APPENDIX A2 to APPENDIX A4.

Table 4.1: A step-by-step results output

Process	**The Output**	
	First Image	**Second Image**
i) Original Image		
ii) Image Filtering		
iii) Image Threshold		

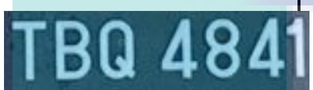
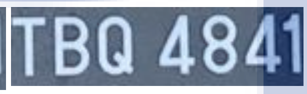
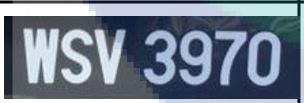
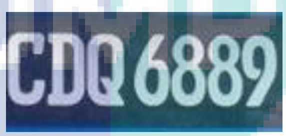
Process	The Output	
	First Image	Second Image
iv) Possible Plate Region		
v) Detected Plate Region		
vi) Marked Plate Region (The Red Box)		

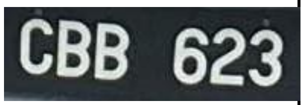
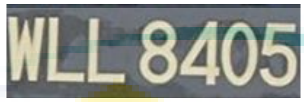
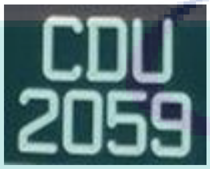
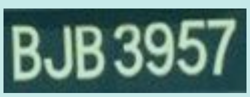
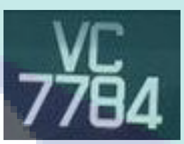
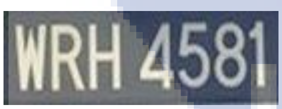
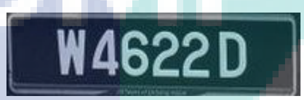
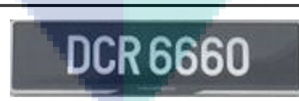
4.2 SEGMENTATION ERRORS FOR PLATE DETECTION ALGORITHM

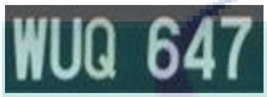
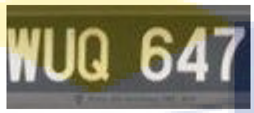
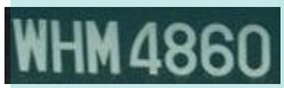
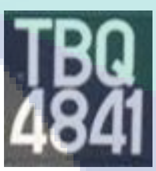
The ANPR system evaluation is split into two stages based on the following reasons. By using the SI images and fed into OCR algorithm, the detected character is extremely bad. As referred to Table 4.2, there are so many plates having lowest detected character and there are some of them did not have detected character at all. Based on the results, we believed, the usage of the smartphone camera with low resolution makes this happened. In addition, lighting effects such as sunlight makes this worsen. Therefore, the images of plate are taken focusing on the plate region only (second dataset) to be fed into OCR algorithm.

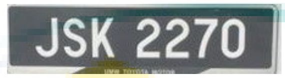
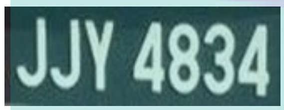
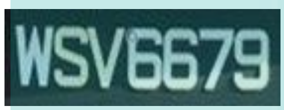
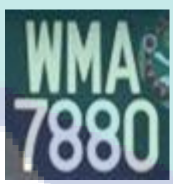
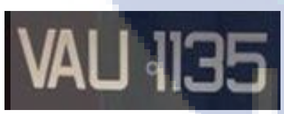
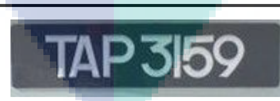
As mentioned previously in Chapter 3, plate recognition algorithm is evaluated based on segmentation errors. Ground truth Image (GTI) is generated manually using image editor tool and the images are then cropped to compare with Segmented Image (SI). Table 4.2 shows the segmentation errors for all of image samples.

Table 4.2: Segmentation errors for the detected plates

No.	Original Image (GTI)	Segmented Image (SI)	Segmentation Errors (%)	Character Detected
1			0.3378	T
2			0.3572	None
3			0.2232	TBQ4841
4			0.4088	None
5			0.2404	None
6			0.2788	3M
7			0.2892	W
8			0.2604	X6
9			0.2856	None
10			0.3674	V
11			0.4708	None

No.	Original Image (GTI)	Segmented Image (SI)	Segmentation Errors (%)	Character Detected
12			0.2608	None
13			0.2774	W8405
14			0.4074	5EL
15			0.2670	I5K
16			0.4038	None
17			0.2770	A
18			0.3974	4
19			0.4436	TE
20			0.4194	VH
21			0.3914	6
22			0.2830	J

No.	Original Image (GTI)	Segmented Image (SI)	Segmentation Errors (%)	Character Detected
23			0.2802	None
24			0.2870	VH
25			0.2450	M
26			0.4840	6L0
27			0.4142	LMGM
28			0.3532	W
29			0.3754	AB
30			0.2666	W
31			0.2208	None
32			0.2996	A
33			0.2258	None
34			0.2748	None

No.	Original Image (GTI)	Segmented Image (SI)	Segmentation Errors (%)	Character Detected
35			0.1956	39
36			0.4090	I
37			0.4020	J
38			0.2660	None
39			0.3290	WT
40			0.2974	0F
41			0.3518	L
42			0.1958	WE
43			0.3870	TJ
44			0.4580	None
45			0.3932	I5
46			0.1784	WW5

No.	Original Image (GTI)	Segmented Image (SI)	Segmentation Errors (%)	Character Detected
47			0.3542	B0
48			0.4778	I
49			0.3800	1
50			0.3988	1W
Average			0.3309	-

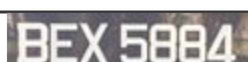
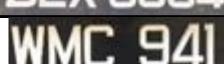
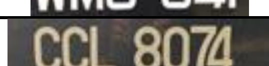
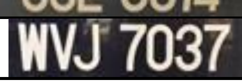
Based on Table 4.2, by average the segmentation errors are 0.3309% and it is considered as very low since it is not even touch 1%. From the observation, highest errors (> 0.3%) occurred when the plates have extra border, wordings, logos, (e.g. plate no. 50, no. 48, no.44, 43, no. 41, no. 4, no. 3, no. 2, no. 1, etc.). Although with this limitation, the algorithms are able to detect the plates with single row and double row type. To further proof the results, several images (taken from Internet) with car plate at beside of car are also fed into the plate detection algorithm. Figure 4.1 shows the detected plate of the samples which is marked with the red box.

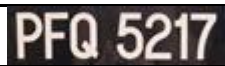
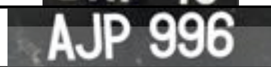
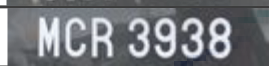
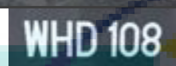
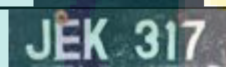
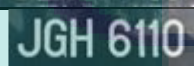
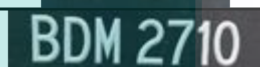
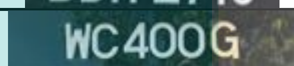
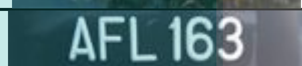
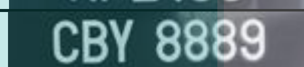
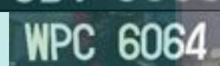
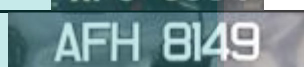
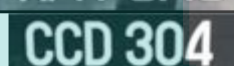
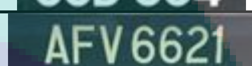
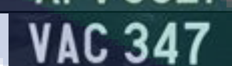
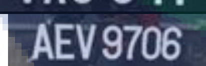
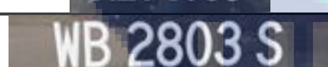
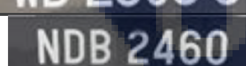
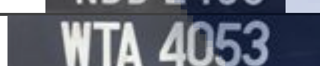
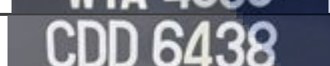
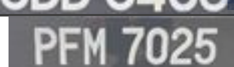
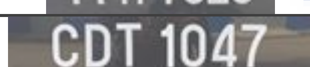
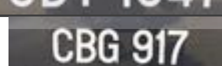
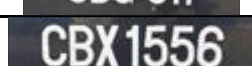
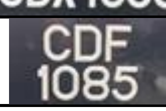
Figure 4.1: Detected plates for other image samples

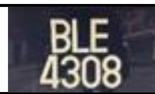
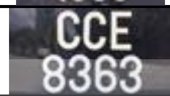
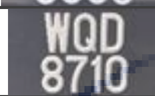
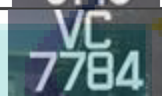
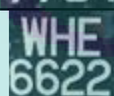
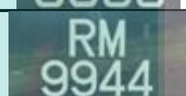
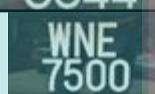
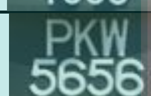
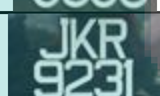
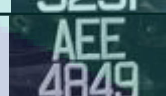
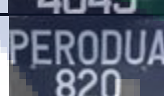
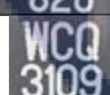
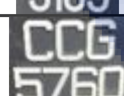
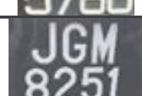
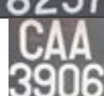
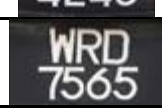
4.3 RECOGNITION ACCURACY FOR OCR ALGORITHM

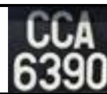
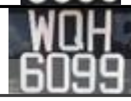
OCR algorithm is evaluated based on recognition accuracy. Table 4.3 shows the recognition accuracy for all of image samples. A step-by-step image output before the algorithm match the character is displayed in APPENDIX B2 and APPENDIX B3.

Table 4.3: Recognition accuracy for OCR algorithm

No.	Plate Image	Character Detected by OCR Algorithm	Recognition Accuracy (%)
1		BEXEBB4	57.14
2		WMDB41	66.67
3		CCL8074	100.00
4		WVJ7037	100.00

No.	Plate Image	Character Detected by OCR Algorithm	Recognition Accuracy (%)
5		PFQ5217	100.00
6		ASKFY	0.00
7		AJP996	100.00
8		HCP3938	71.43
9		WHD108	100.00
10		JLK377	66.67
11		JGH6110	100.00
12		BDH27T0	71.43
13		WC400Q	83.33
14		AFL63	83.33
15		CBY8889	100.00
16		WPC6064	100.00
17		AFHBT4B	57.14
18		CCD304	100.00
19		AFV662T	85.71
20		VAC347	100.00
21		AEV9706	100.00
22		WBZ803S	85.71
23		NDBZ460	85.71
24		WTA4053	100.00
25		CDD6439	85.71
26		PFH7025	85.71
27		CDT1047	100.00
28		CBG917	100.00
29		CBX1556	100.00
30		CDF10B5	71.43

No.	Plate Image	Character Detected by OCR Algorithm	Recognition Accuracy (%)
31		BLE4308	100.00
32		CCE8383	71.43
33		W0D8710	85.71
34		VC77B4	83.33
35		WHE6622	100.00
36		DAHEZBB	28.57
37		RM9944	100.00
38		WNE7500	100.00
39		PKW5656	100.00
40		JKRB2B7	57.14
41		AEE4B4B	71.43
42		PERODUA820	100.00
43		WCO3109	85.71
44		EEB57BDJ	42.86
45		JGV8257	71.43
46		CAA39D6	85.71
47		WOR4243	85.71
48		WRD7555	85.71

No.	Plate Image	Character Detected by OCR Algorithm	Recognition Accuracy (%)
49		LLA6390	71.43
50		WDHLBDBB	28.57
Average			82.24

Based on Table 4.3, the average recognition accuracy achieved is 82.24% which is good enough for this kind of system. However, the system could not recognise the character when the plates having massive light reflection such as the sample from image no. 50, no. 1, no. 6, no. 17, etc. Other than that, the system has a problem in recognising character with not the same with character template. For example in Figure 4.2, the system confused to decide image (a) and this resultan image (a) as an “B” and not “8”. As referred to Table 4.3, image no. 2, character “2” is recognise as “Z”, no. 3 character “Q” is recognise as “0”, etc.

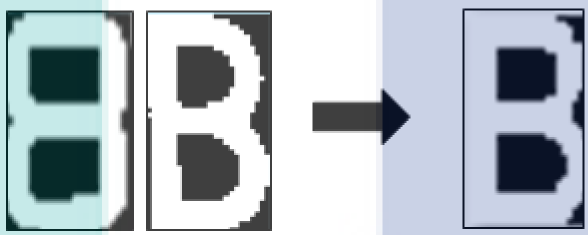


Figure 4.2: Sample of characters recognition in OCR algorithm

4.4 GRAPHICAL USER INTERFACE LAYOUT

Graphical User Interface (GUI) is developed to ease the user experience on using the system as well as to get an effective results displayed for performance evaluation. Figure 4.3 to Figure 4.5 illustrates the layout of the GUI.

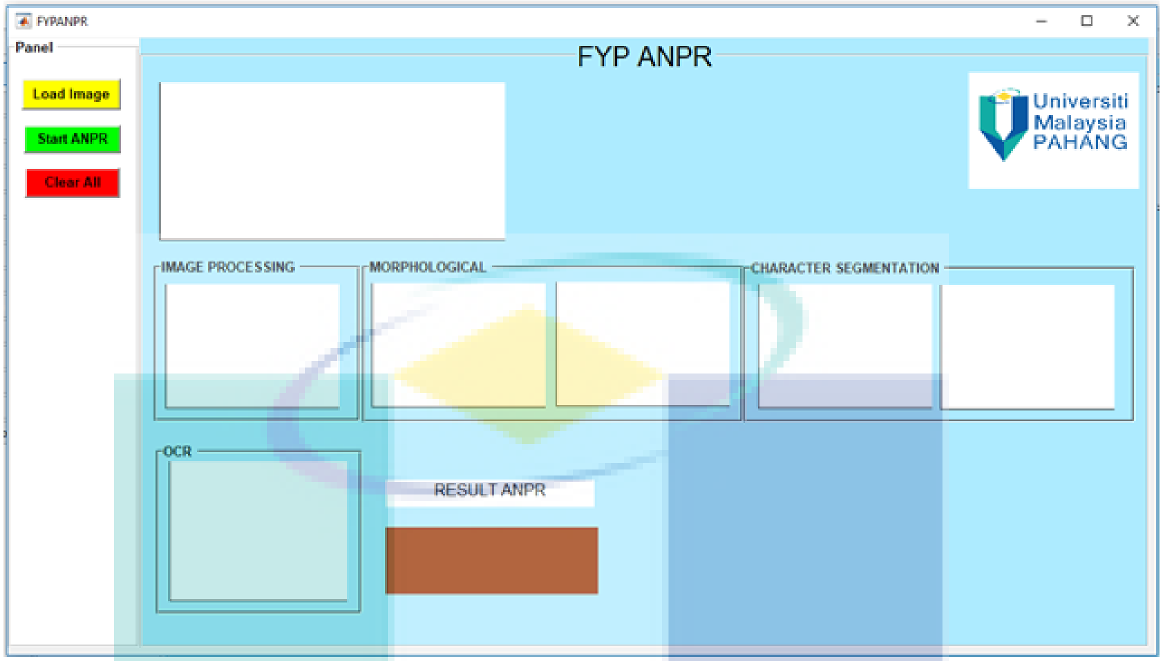


Figure 4.3: Main page layout

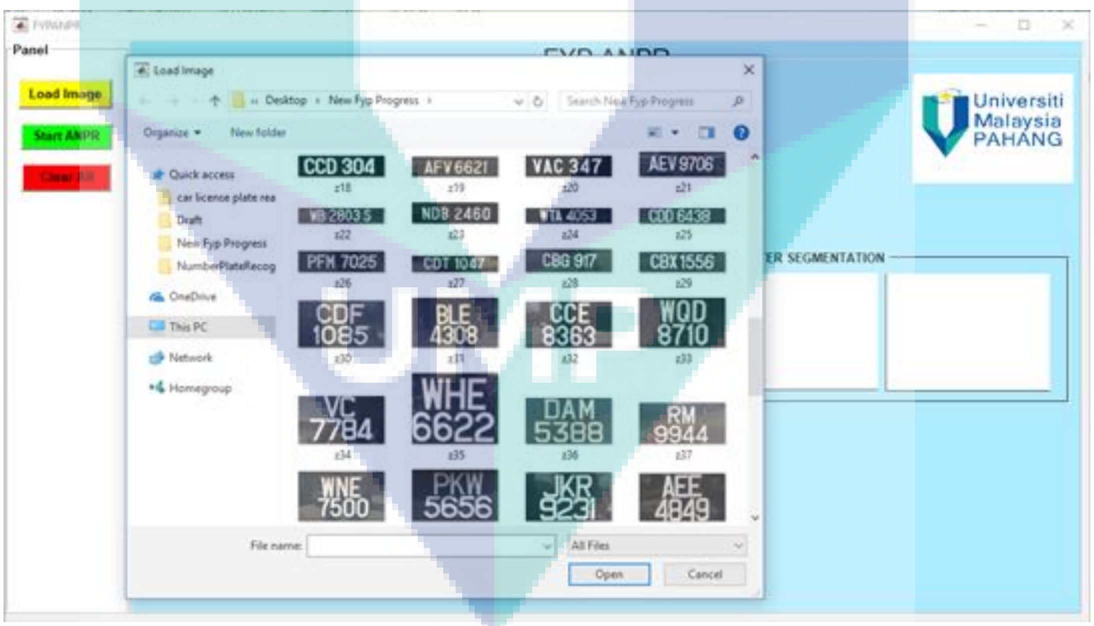


Figure 4.4: Loading the plate image to start the system

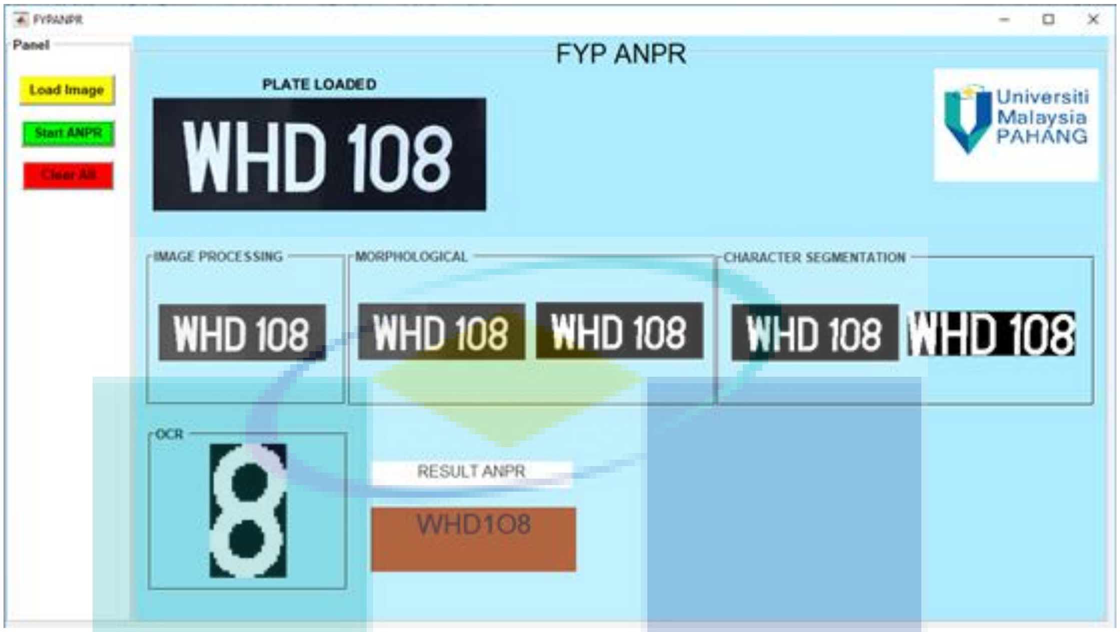


Figure 4.5: A step-by-step output and results showing on GUI

CHAPTER 5: CONCLUSION AND RECOMMENDATION

The main of this research is to develop ANPR system in order to detect the presence of cars in the parking lot. The objectives of the research is achieved and the system is now able and ready to be used with some limitations although it gives more than 80% recognition accuracy. The system is also qualified to detect the plate region with less than 1% segmentation errors. Some improvements and recommendations to further upgrade the system:

i. The system should be tested using the images taken from specific surveillance camera;
ii. The algorithms can be improved by adding advanced image enhancement techniques to reduce the reflection errors;
iii. Adding more character templates in order to solve non-standard plate issues;
iv. Instead using template matching technique, ANPR system can also use statistical matching technique in OCR algorithm;
v. The system is also need to be evaluated on different vehicles such as lorry, bus, motorcycle, etc.
vi. In real situation, the system also must have capabilities to automatically detect cars and snap a picture of it.

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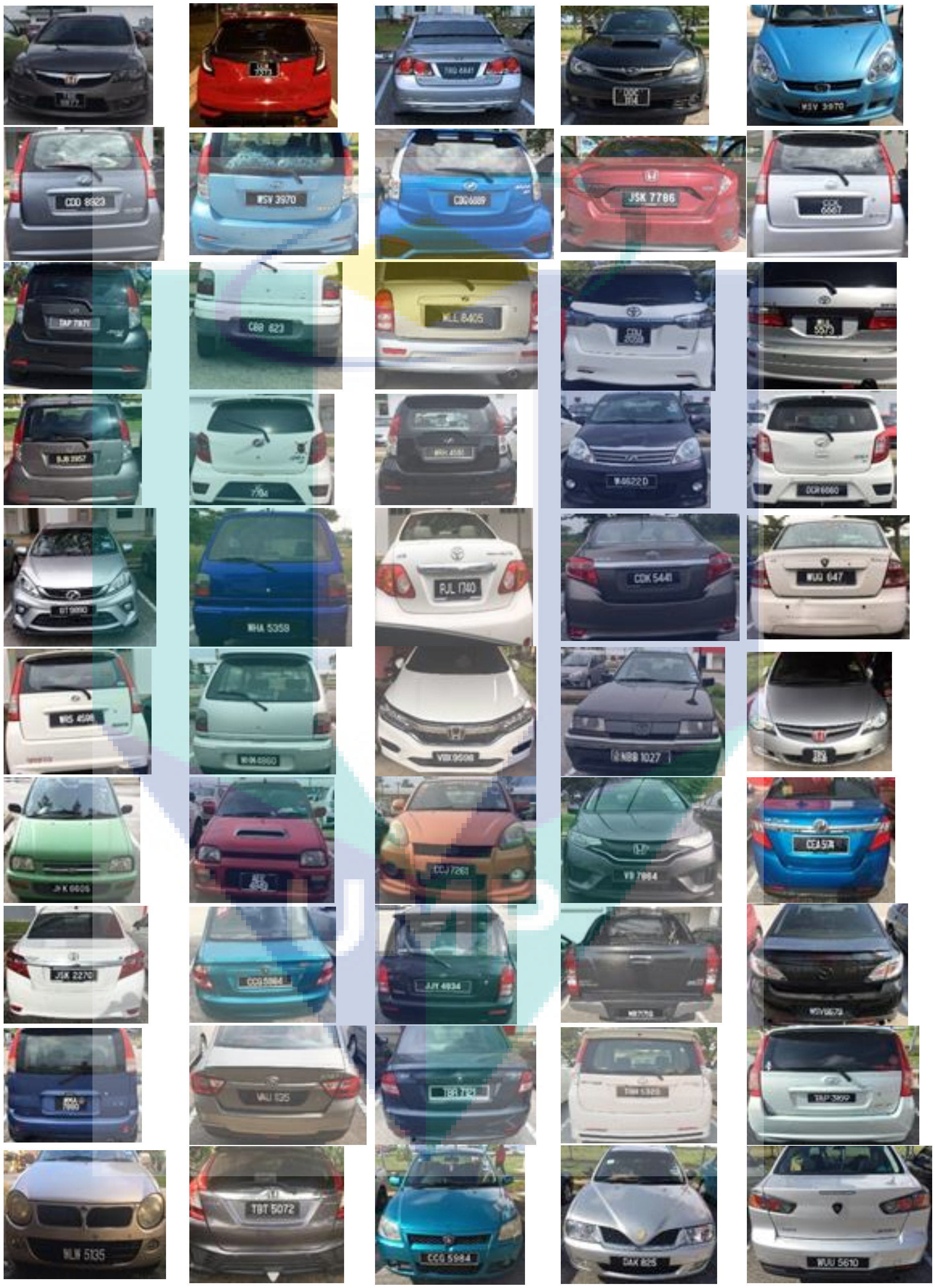
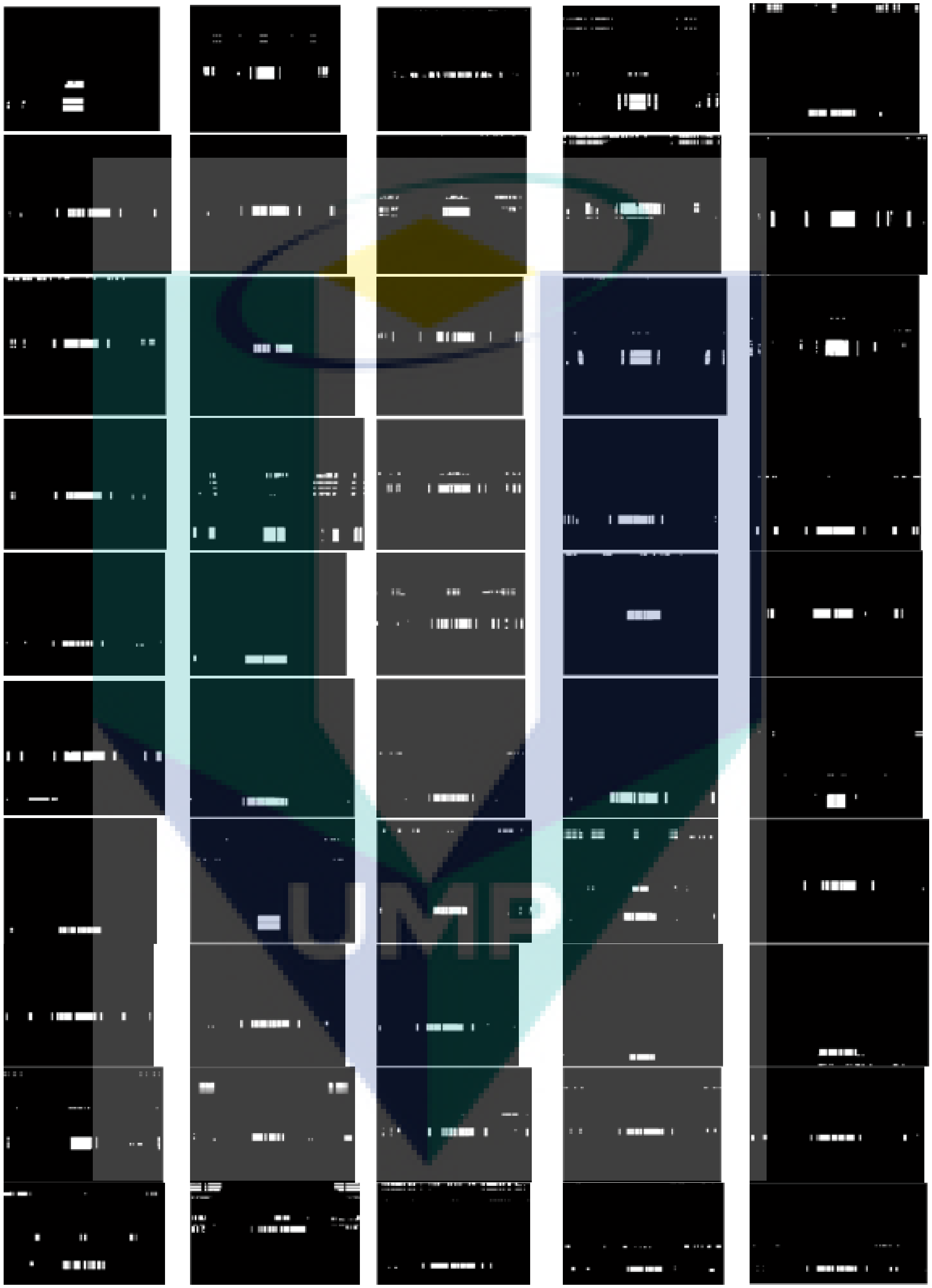
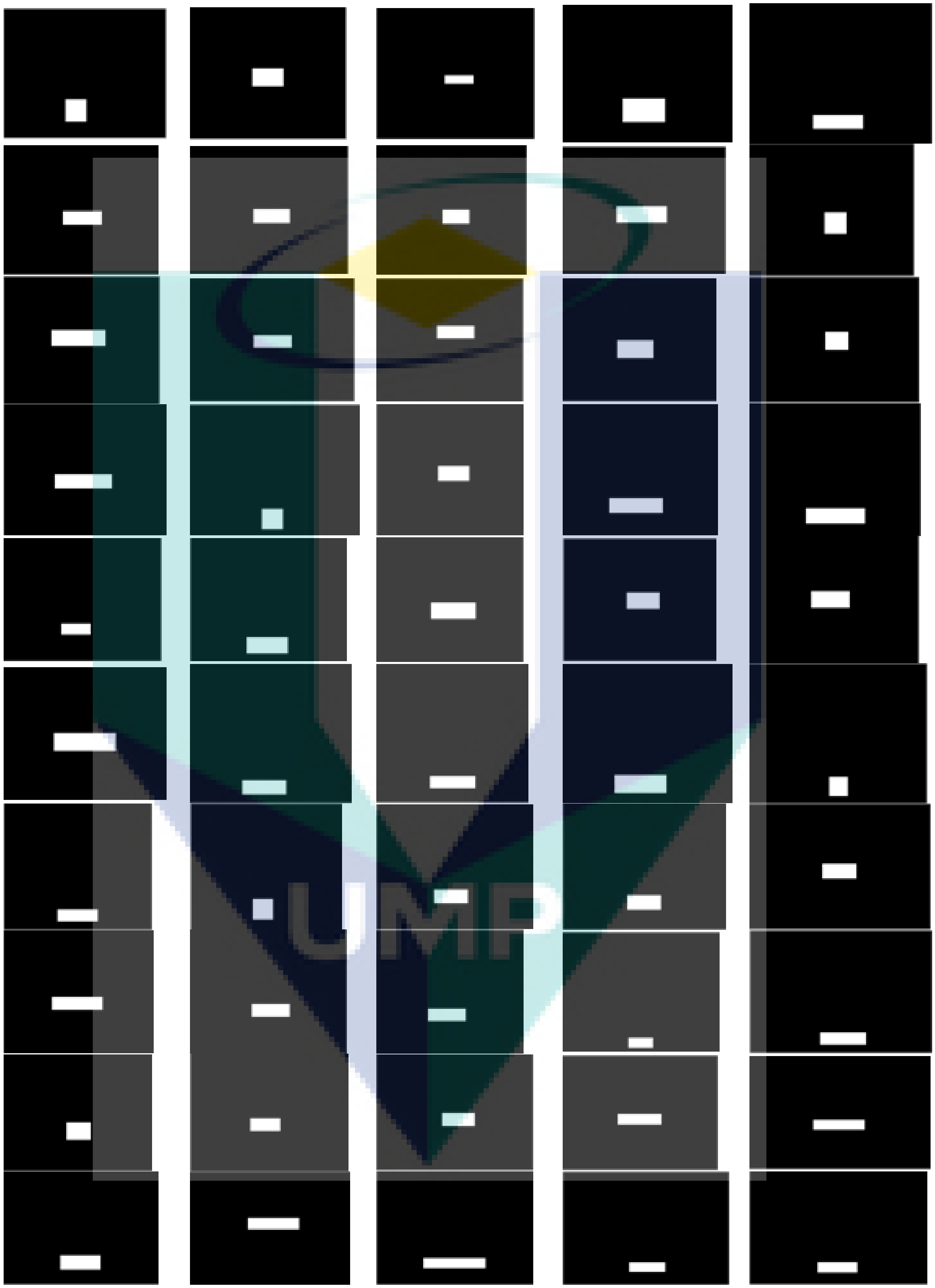
APPENDIX A1: IMAGE SAMPLES (FIRST DATASET)



APPENDIX A2: POSSIBLE PLATE REGION



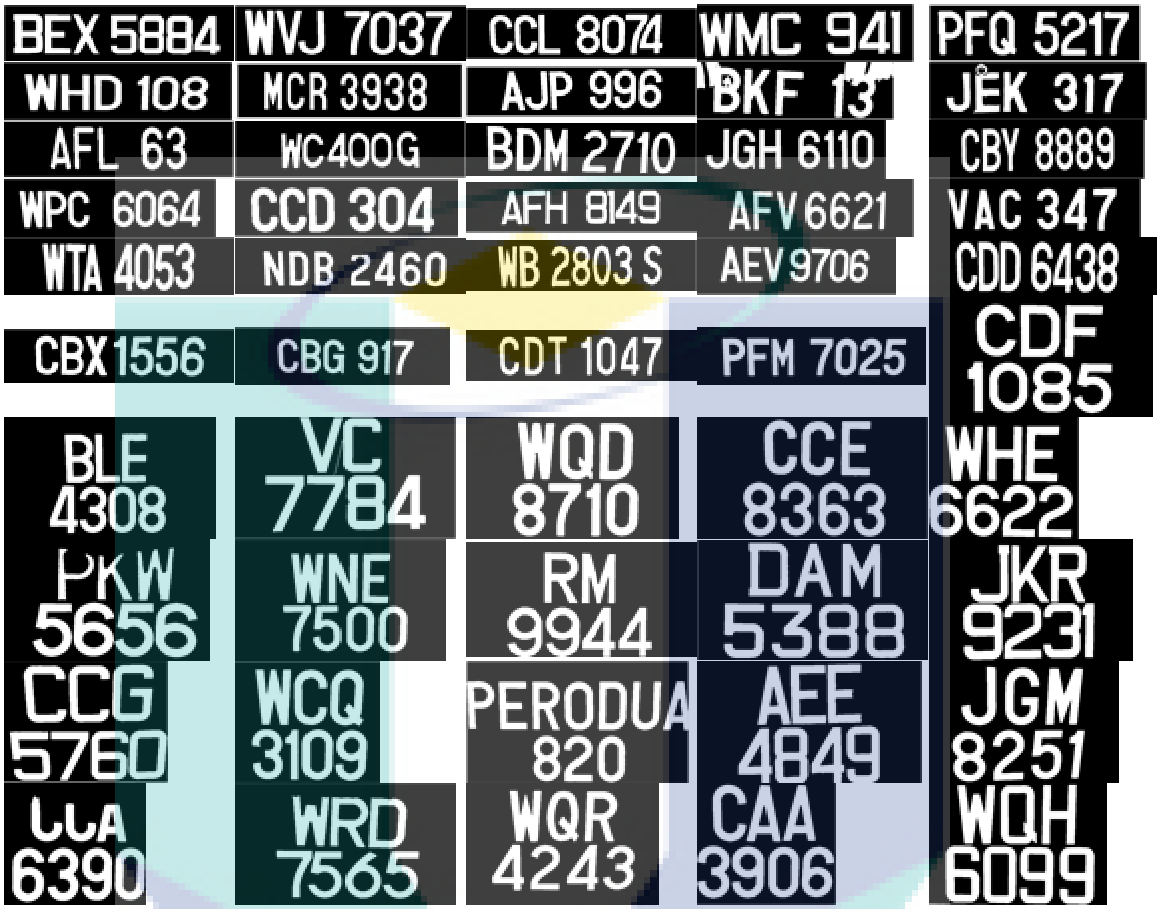
APPENDIX A3: DETECTED PLATE REGION



APPENDIX A4: DETECTED PLATE REGION MARKED IN ORIGINAL IMAGE

APPENDIX B1: IMAGE SAMPLES (SECOND DATASET)

APPENDIX B2: IMAGE BINARISED



APPENDIX B3: IMAGE READY FOR OCR