Vehicle License Plate Registration Recognition System

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ABSTRACT

The strategy of the project is to design automatic system for opening a gate without mounting any signal transmitter on the car. Thus, the project is to investigate and construct an application whereby the system will recognize the Vehicle license plate at a gate entrance of the parking lot. The system will be based on a personal computer and software packages available, MATLAB program and a digital camera, which help to capture the images of the vehicle license plate.
We will conduct a research and developed a system that is able to extract the vehicle license plate. Next, we also need to create an algorithm to train and identify the vehicle license plate for the purpose of recognition.
The general algorithm involves the following steps:

- Image Processing : The image captured is preprocessed and reduction in the contrast.
- Plate localization and extraction: To obtain the vehicle plate sub image.
- Character Segmentation/Recognition: Resample and threshold in order to isolate the license plate and vehicle license plate character. We used neural network for recognition of vehicle license late character. The neural network will be trained off-line with the characters and numbers.
- Evaluating the performance of the algorithm and compare the performance with other reported work.
- Implementing a file management system or database for storing the images of vehicle license plate, numbers and characters

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1 INTRODUCTION

1.1 Project Background

Vehicle License Plate Recognition is an image processing system whereby it is used to recognize the vehicles by identifying the license plate. It is basically use for traffic and security purposes.

How the Vehicle License Plate System works

Firstly, the vehicle will stop at the car gantry. The cycle will start when the vehicle steps over the detector. It will activate a signal to the Vehicle License Plate System of the presence of the vehicle.

Secondly, illumination (infra-red) will be activated and images of the front picture of the vehicle will be taken. The system will read the information pixels of the vehicle and run the recognition process.

Thirdly, the system will apply certain algorithm to analyses the vehicle image. Besides analyzing, the images will be enhance, locating the vehicle plate position and extract the characters from the vehicle plate. Next, the characters will be recognized by using Neural Network

Lastly, the system will try to match the recognized vehicle plate number with the car plate database. If “Access Granted”, the gantry will open and allowed the vehicle to pass through. Diagram is illustrate in Fig 1

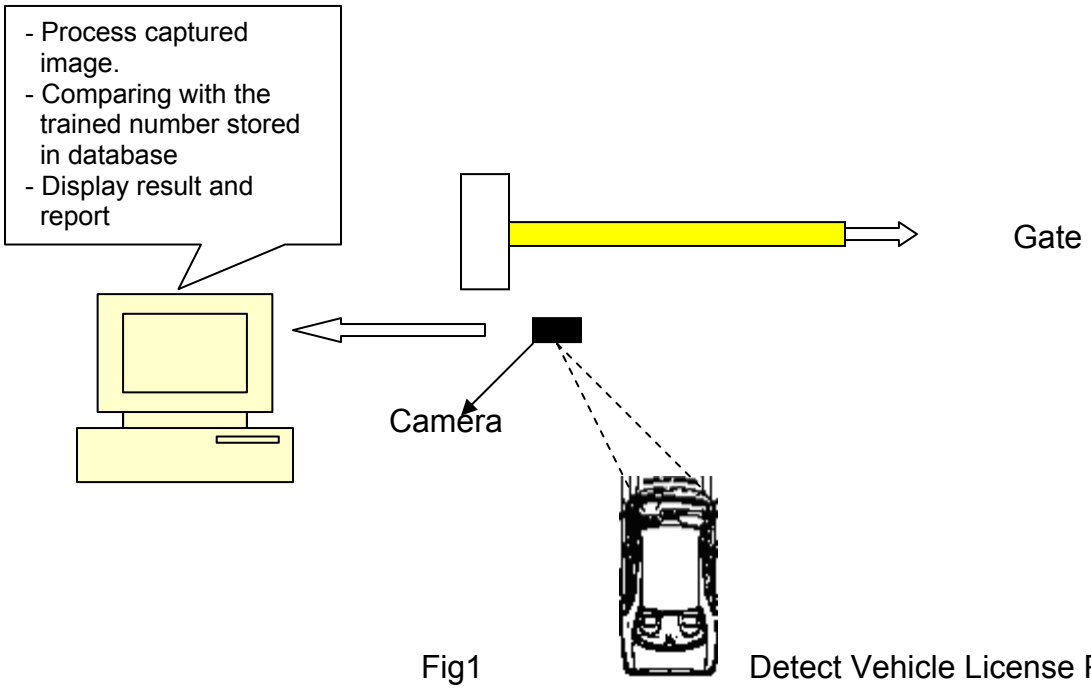


Fig1 Detect Vehicle License Plate

Besides, the Vehicle License Plate Recognition also provide an advantage by keeping the image of the vehicle in which it will be useful for crime fighting. Camera can also focus on the face of the driver and save it for security reason.There are difficulties for Vehicle License Plate Recognition in which it will affect the efficiency and accuracy of the system. It is essential and important to determine the facts which will able to influence the operations and recognition proficiency. Next, we also need to look into other facts of variables that are not constant. Below are the non-constant variables which will affect the accuracy of recognition:

- Speed of the vehicle
- Weather condition
- Type of Vehicle
- Distance between vehicle license plate and the camera
- Type of plate (Rectangular, Bent type)
- Vehicle license plate orientation
- Type of vehicle fonts character

1.2 Objectives

The overall objective of the project is to develop a system to recognize vehicle license plate from a car at a gate entrance of a parking lot. The software could lead to a cheaper and faster way of enhancing and determined the performance of the recognition system. The system will be based on a Personal Computer such that it will generate report on the vehicle license plate it has captured.
Once the vehicle license plate is captured, the characters will be recognized and displayed on the Graphical User Interface. Besides, the system can also serve as a security purpose whereby it can spot on any wanted or stolen vehicles.
In the past, there has been similar project implemented but had poor accuracy. Thus, we would need to improve or rewrite the algorithm to improve the accuracy. I will address a set of constraints and focus on the design of the algorithm to extract the vehicle license plate in order to improve the accuracy.

There is definitely a lot more room for further improvement on this project. However, due to the limited time frame given, it is not advisable for me to cover all aspects in this project. Thus, in discussion with my tutor, we managed to come up with the progress guideline as to what need to be included in this project.

1.3 Constraints

Due to limited time that we possess and dealing with image vision software, it is not advisable to include all of the possible cases. Thus, we have to set a list of constraints to make the project more systematic and manageable. The constraint is listed as below:

- Image taken only when vehicle is stationarY
- Captured image of vehicle at fixed distance.
- Captured image of vehicle at fixed angle
- There will be no motion capture image
- The vehicle license plate position should be captured centered
- The image should be taken with the height of 50cm to 70 cm above the ground level.
- Take only the front view image of the car.
- Try on zoom in image of the car and image consists of headlamp
- Captured images on location where light is proportional
- Deal with only Singapore Car License Plate (shown in Fig 2)

Fig 2

1.4 Various Type Of Vehicle License Plate

- **What is Car license Plate**

Car license Plate is a rectangular metal plate which consists of a combination sequence of alphabet characters and numbers issued by the government for identification purpose of registered vehicle.

- **Private Vehicles**

Vehicle owner who register the car as private vehicle are allow to choose the white one in the front plate and yellow in the back plate .Alternatively , they can choose black number plate on both sides too.

- **Various type of Regisration Numbers**

There are a variety of registration numbers that start with specific letter. The type of class series are shown below:

- **A** series: Motorcycles
- **CB** series: Company / school buses
- **F** series: Motorcycles
- **FB** series: Motorcycles
- **G** series: Goods vehicles
- **P** series: Private buses
- **Q** series: Company vehicles
- **SH** series: Cab/Taxi
- **W** series: Heavy vehicles
- **X** series: Heavy vehicles
- **Y** series: Heavy vehicles

- **Off-peak Vehicles or Weekend Car**

“Off-peak Vehicles” is also known as Weekend Cars. Vehicle registered under this series will pay cheaper road tax compared to other series of vehicle. The displayed license plates contain red background with white characters and numberings. The operation hours for “Weekend Cars” in Singapore is (7pm to 7am) on weekdays; after 3 pm on Saturday; full day on public holiday and Sunday.

- **Various Types and Design of Car License Plate in Singapore**

1) ABC 1234D

2) ABC 1234D

3) ABC 1234D

4) ABC 1234D

5) ABC1234D

Fig 3

Different type of characters design for various car plates

Fig 4

2 Main Text and Discussion

2.1 INTRODUCTION TO MATLAB

MATLAB is chosen as the main development for the license plate recognition application. The task is to construct the algorithm and recognizes can be done using MATLAB.
Besides, MATLAB is also very efficient as it have built-in-function tools for neural network and image processing.
The advantages of MATLAB can be classified as follows: Platform independence, predefined function and device-independent plotting, Graphical User interface and MATLAB compiler.

Comparison of MATLAB with other program is shown in the below diagram.

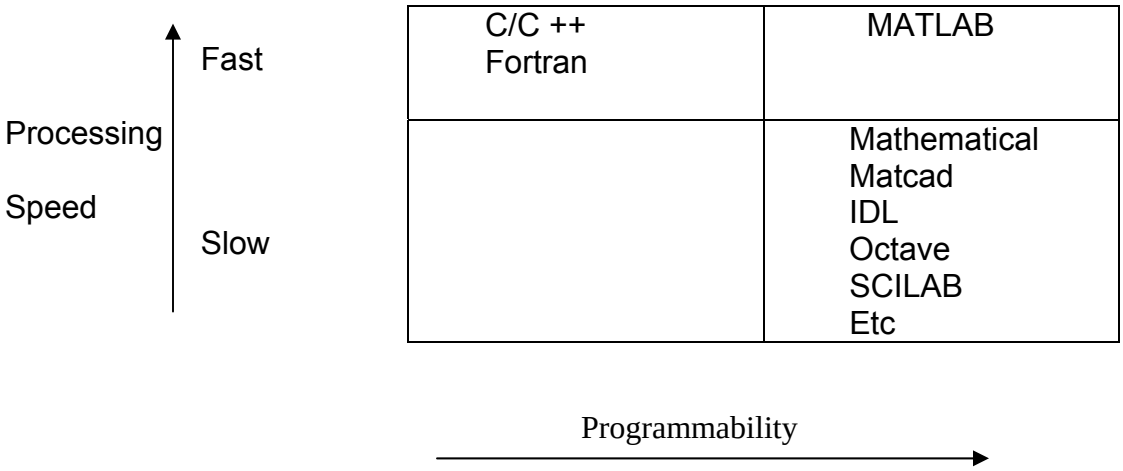


Fig 5

MATLAB read images using the function "imread". The table below show images/graphs format that is supported by "imread" with MATLAB.

Format Name	Description	Extension
TIFF	Tagged Image File Format	.tif ; tiff
JPEG	Joint Photograph Experts Group	.Jpg ; .jpeg
GIF	Graphic Interchange Format	.gif
BMP	Windows Bitmap	.bmp
PNG	Portable Network Graphics	.png
XWD	X Window dump	.xwd

2.2 Comparison Between MATLAB and Artificial Intelligence

- **Advantage of Artificial Intelligence:**

1. Good for solving complex problems where humans or programmer have expert knowledge in it.
2. Non-programmers can easily understand the rules of artificial intelligence.
3. We can changed and add individual rules

- **Disadvantage of Artificial Intelligence:**

1. There are difficulty in getting expert knowledge and putting it in used in the system.
2. Not good in common sense reasoning
3. Expensive
4. Slow response
5. Unpredictable

- **Advantage of MATLAB**

1. Data can be represented in terms of matrices or vectors.

2. MATLAB coding is shorter and simpler

3. Algorithm used in MATLAB can be converted to use in hardware.

4. The system will perform faster when using “Matrix Approach”.

5. MATLAB possess power graphic visualization tools.

2.3 OVERVIEW OF THE VEHICLE LICENSE PLATE SYSTEM

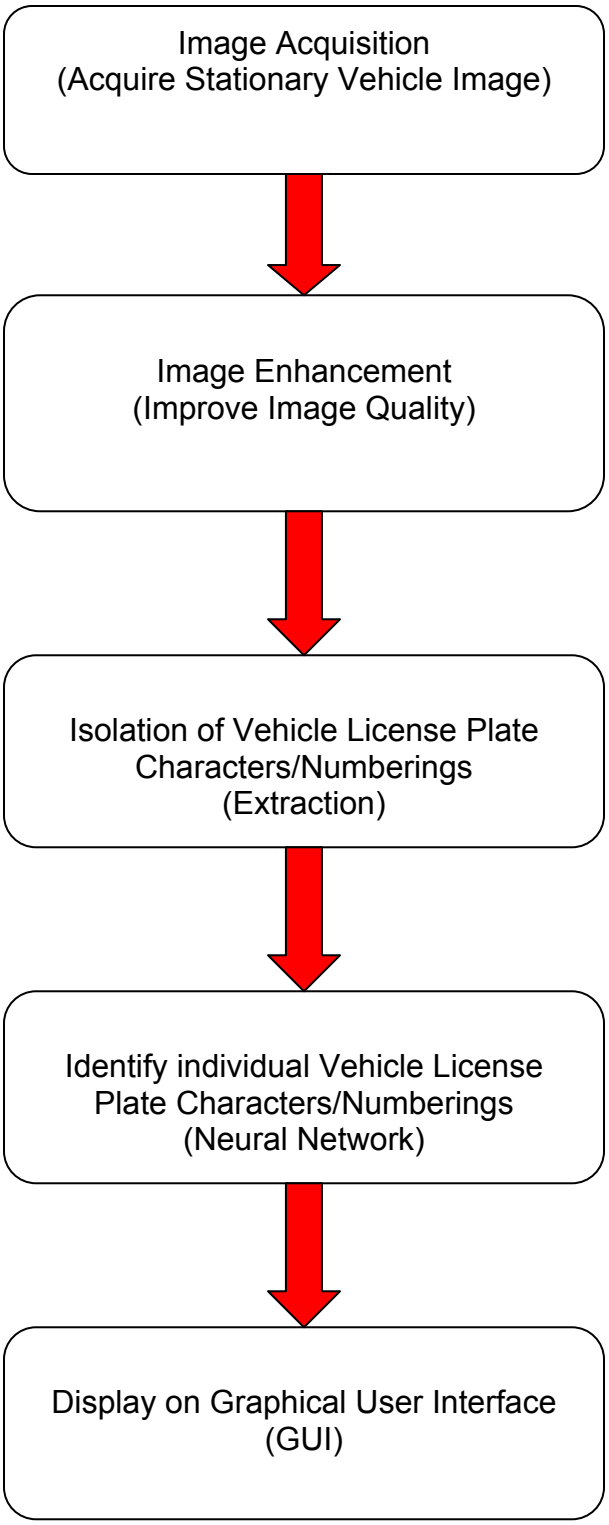


Fig 6

3 Image Acquisition

The initial phase of image processing for Vehicle License Plate Recognition is to obtain images of vehicles. Electronic devices such as optical (digital/video) camera, webcam etc can be used to capture the acquired images.
For this project, vehicle images will be taken with a Panasonic FX 30 digital camera. The images will be stored as color JPEG format on the camera. Next, we might proceed in using the Matlab function to convert the vehicle JPEG image into gray scale format

3.1 Image Cropping

Image cropping is a recognition process whereby it will extract the smallest rectangle which will contains the edge of the license plate and license plate itself. As the license plate surrounding is of no importance, this cropping process will highly increase the speed of image processing. The **figure** below shows the copping of image:

Original Figure

Cropped Figure

Fig 7

3.2 Conversion of RGB Images to Binary Images

In order facilitate the next process smoothly and reducing the processing time, the image obtain is being converted to Binary Image. The conversion is done by using the toolbox in MATLAB (im2bw).

3.2a What is Binary Images

It is an image which quantatised into two values representing 0 and 1 or in pixel values of 0 and 255 representing the color black and white.

Binary images is the simplest process and has apply to many other application. It is useful as the information we need can be obtained from the silhouette of the object. The application is as:

- Text interpreting
- Identify the object orientations

Next, Binary Images are obtained by converting the input image into grayscale format, then by converting the grayscale image to binary image by thresholding. The image is made up of a matrix squares which is called Pixel. Each pixel in the image has a brightness value which is known as grey level.
The pixel of grey level above the threshold will be set to 1 (equal to 255; white) and the rest will be set to 0 (black). We will obtain white object with black background or vice versa.

The characteristic function for the image object is classify below:

B(x,y) { 0 = points on the object
1 = points at background

Binary Image

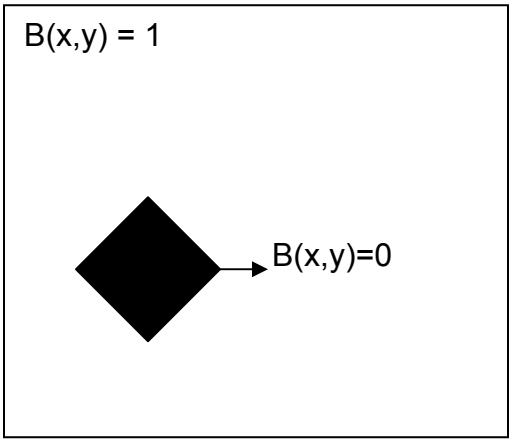


Fig 8

Below will illustrate different type of histogram images

Histogram of light object with dark background.

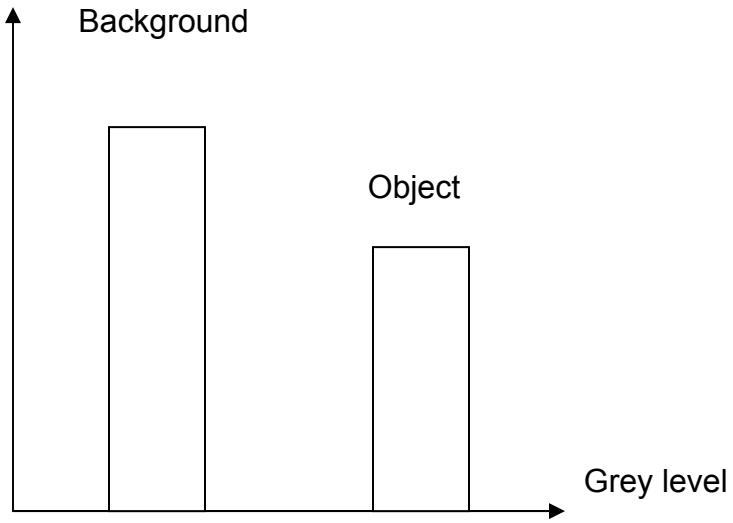


Fig 8

Histogram of object and background which is close

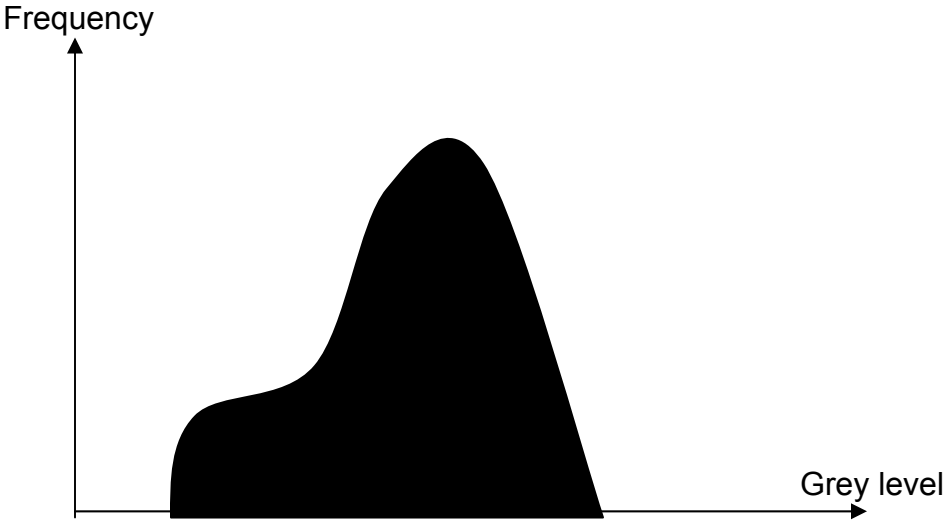


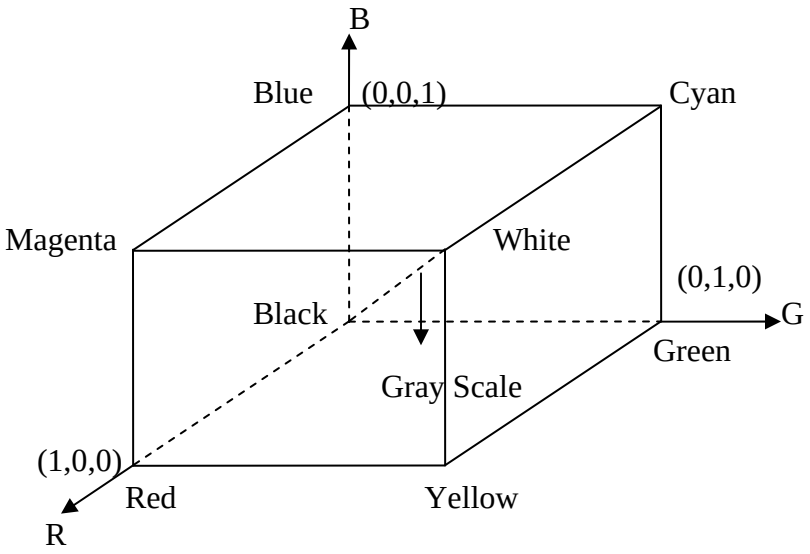
Fig 9

In this circumstances, there is difficulty in choosing the threshold as the histogram is no more bimodal This root cause is due to the variations of light or colours in the images.

3.3 Color Image Processing

RGB Color Space

The RGB image is made of color pixels of an M x N x 3 array. The color space is normally graphically shown as RGB color cube. The cube vertex consists of the primary color (Red, Green and Blue) and the secondary color (Cyan, Magenta and Yellow). The schematic of the RGB cube that illustrate both the primary and secondary color at each vertex is shown below.



RGB Schematic Block diagram

Fig 10

3.4 HSV Color Space

HSV color space consists of three important components in it. They are namely the: Hue component, Saturation component and the Value component.

Hue: It is shown in a circular region and can be an angular measurement. Red color will represent a hue value of 0; Green color will represent a hue value of 120 and blue color will represent a hue value of 240.

Saturation: It is the of the vector distance from the center to the point. The saturation with value of 0 is completely white; saturation with value of 1 or maximum (hexagon outer edge) is colorfulness.

Value: This refers to the lightness or brightness in the HSV color space. The color will be dimmer if the Value is low. The color will be brighter if the Value greater.

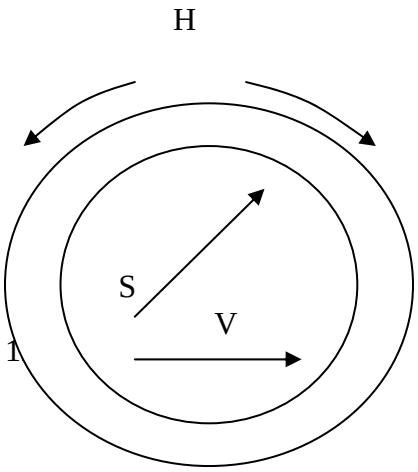


Figure showing the wheel of HSV.

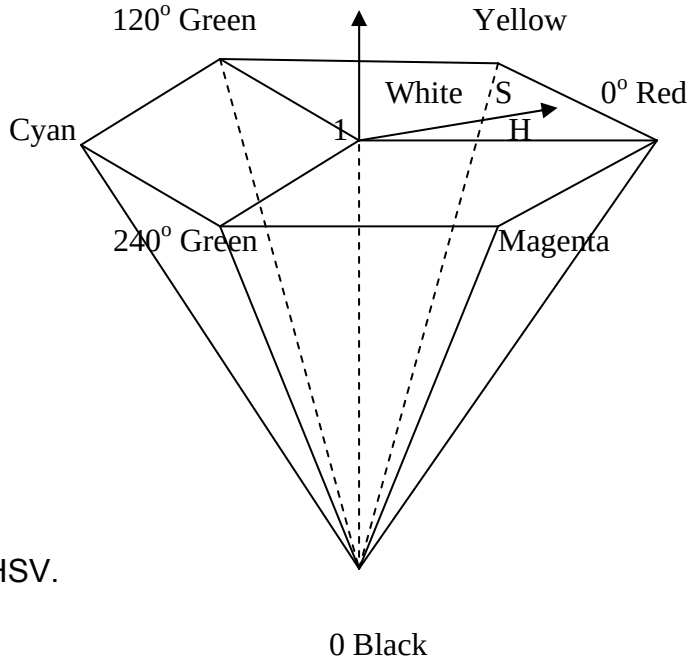


Figure showing Hexagonal cone for HSV

Fig 11

3.5 Conversion from RGB to HSV

Assume Red, Green and Blue be the coordinate of the color and values be the real number between 0 and 1.
Let maximum (max) be the gradient of Red, Green and Blue and minimum(min) be the least of the values.
The below equation show how to determine value of the hue:

(i) $$\left[60^{o} \times \frac{G-B}{Max-Min} \right] + 0^{o}$$,Given max = 1 and G is greater or equal than B

(ii) $$\left[60^{o} \times \frac{G-B}{Max-Min} \right] + 360^{o}$$,Given max = r and G is smaller than B

(iii) $$\left[60^{o} \times \frac{B-R}{Max-Min} \right] + 120^{o}$$,Given max = G

(iv) $$\left[60^{o} \times \frac{R-G}{Max-Min} \right] + 240^{o}$$,Given max = B

The below equation show how to determine value of the Saturation:

Saturation (s) = $L = \frac{Max + Min}{2}$

0 if L=0 and max = min ;

$\frac{Max - Min}{Max + Min} \quad \frac{Max - Min}{2L}$ Given $0<L<\frac{1}{2}$;

$\frac{Max - Min}{2-(Max + Min)} \quad \frac{Max - Min}{2-2L}$ Given $L>\frac{1}{2}$;

Thus, s = 0 , if maximum = 0;

$\frac{Max - Min}{Max}$, otherwise

The hue value is normally between the anngle of 0 and 360 and the hue value is 0 if the maximum is equal to minimum.

The below equation show how to determine value of the Value:

V = Max

3.6 RGB To CMY Color Space

Cyan, magenta and yellow is known as the secondary colors of light. For example, if the color is seen as cyan with white light illumination and no red pigment being reflected from the surface. Likewise, the cyan subtracting the ed light, magenta subtracting the green light and yellow subtracting the blue light from the reflected white surface.
The conversion is given as:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Performing of RGB to CMY conversion is suitable for printing of images due to its nature of color links

4 IMAGE ENHANCEMENT

The aim of this process is to increase and improve the visibility of the image. Image Enhancement techniques consists process of sharpening the edges image, contrast manipulation, reducing noise, color image processing and image segmentation as well. The process can fall into two categories: Histogram Processing and Spatial domain.

4.1 HISTOGRAM PROCESSING/EQUALIZATION

The Histogram image equalization is the process whereby the preceding transformation will generate an image that will show a histogram at each intensity level. The net result of the process will yield an image with an increased sparse range of intensity and higher contrast compare to the original image.
The processed image from the histogram is not uniform due to the discrete nature. The RGB image value in a range of pr(rj); j=1,2,…..,L; represent the histogram with the level of the intensity of the given image. Thus the main aim of the histogram is to look for a transform S(k) = T(rk)

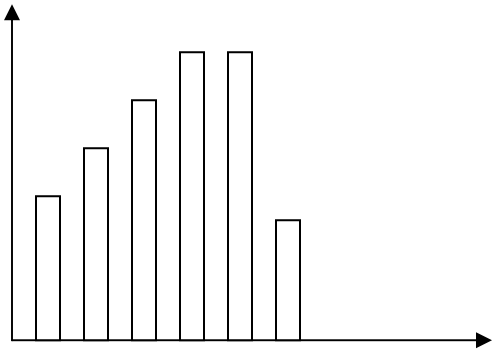
$$= \sum_{j=1}^{k} pr(rj)$$

$$= \sum_{j=1}^{k} (nj / n)$$

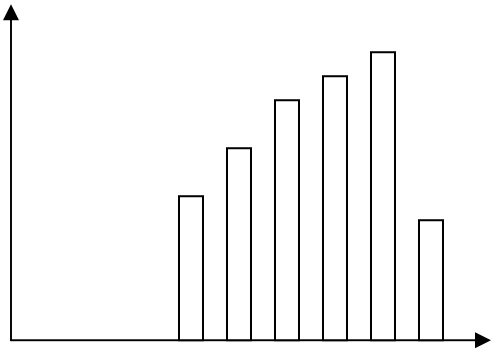
where sk represent the output value of the intensity and rk is the input image

Histogram equalization produced an adaptive transformation function and the histogram will not change unless there is any change in the image. Histogram matching is very similar to Histogram equalization but it need to specify the histogram shape in which it is able to highlight the given image grey level range.

Images showing different kind of Histogram



Dark Image



Bright Image

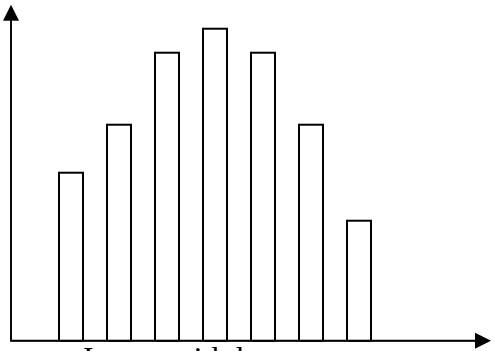


Image with low contrast

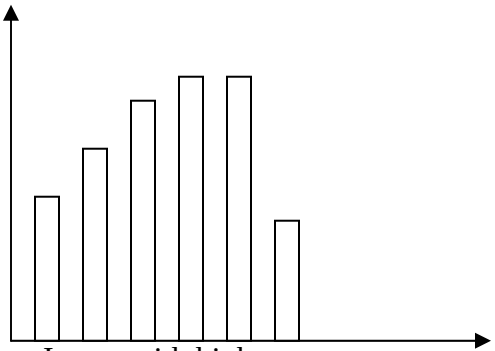


Image with high contrast

Fig 12

4.2 IMCOMPLEMENT

Imcomplement will compute the complement image(IM). IM can intensity, binary or true color image. For the complement binary image, black will becomes white and white will be come black ; zeros will become ones or ones will become zeros.
For the complement of the true color image, the value of each pixel will be subtracted by the maximum pixel value which is supported by the class. The pixel value obtained by the differences will be used in the output image. Therefore, the light areas will become darker and the darker area will become lighter.

5 Thresholding

Image thresholding enjoys the central position of any application in the process of image segmentation. One of the simplest process will be the Gray-level thresholding. The regions of the images are classified by the reflectivity and absorption of light on its surface.
Thresholding is one of the oldest segmentation method. It is still greatly used in applying on the applications in the market due to certain reason; Fast and cheap.
The value of threshold (T) is being selected and compare with the pixel of the image. It also transform the input image(K) into an output binary image (F) which is being segmented.

F (x,y) = 1 if K (x,y)>=T;
= 0 if K (x,y)<T

Representing F (x,y) =1 for image object; F (x,y) = 0 for background of the object and T = threshold.

There are several type of thresholding. They are namely the Global thresholding, Local thresholding and the Optimal thresholding.

5.1 Global Thresholding

This is a method whereby the histogram of the image is being partitioned using a single threshold value. Image is form up of square matrixes called pixels and each pixels in the image have a brightness level known as gray level. The value of the gray level varies from the darkest (0) to the brightest (255)
The threshold define the value of the gray level in which the baseline boundary is in between the foreground pixels and the background. We can use the graythresh toolbox function to calculate the threshold value by using Otsu's method. The threshold value which is selected is use to reduce the intraclass variance between the white and black pixels.

5.2 Otsu's method

Otsu's method works out based on the discriminate analysis. The threshold chosen is by partitioning the image pixel into two classes: C0 and C1, (Foreground and Background)
We will used the function provided by the Matlab toolbox called graythresh which will calculate the threshold old value using Otsu's method. To examine the histogram-based method, The probability density function is as:

$Pr(rq) = nq/n$
where q =0,1,2,3……,L-1
n = total pixel in an image
nq = number of pixel which have intensity level rq
L = image intensity level

Assuming threshold k is being chosen and C0 with pixels level of (0,1,2…..,k-1) and C1 with pixel level of (k,k+1,……..,L-1). Otsu's method used the threshold value k in which it maximize the between-class variance σ^2_B. It will be defined as

$\sigma^2_B = \omega_0(\mu_0 - \mu_T)^2 + \omega_1(\mu_1 - \mu_T)^2$ where

$$\omega_0 = \sum_{q=o}^{k-1} Pq\,(r_q) \quad ,$$

$$\omega_1 = \sum_{q=k}^{L-1} Pq\,(r_q)$$

$$\mu_0 = \sum_{q=o}^{k-1} qPq\,(r_q)/\,\omega_0$$

$$\mu_1 = \sum_{q=k}^{L-1} qPq\,(r_q)/\,\omega_1$$

$$\mu_T = \sum_{q=0}^{L-1} qPq\,(r_q)$$

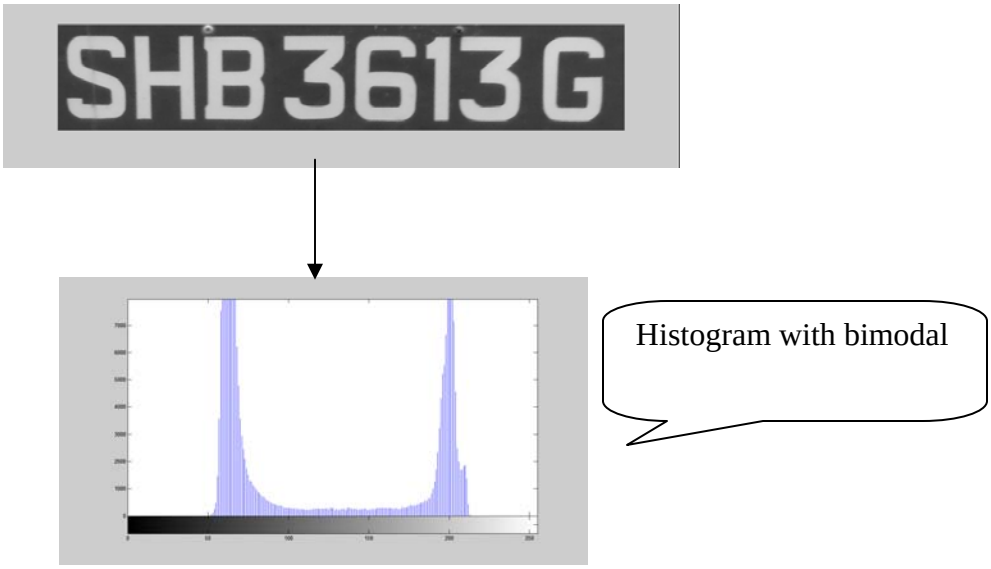
The graythresh will compute the image histogram and determine the value of the threshold. The threshold value will returned as a normalized value between 0 and 1. The graythresh syntax is as :

T = graythresh(f)

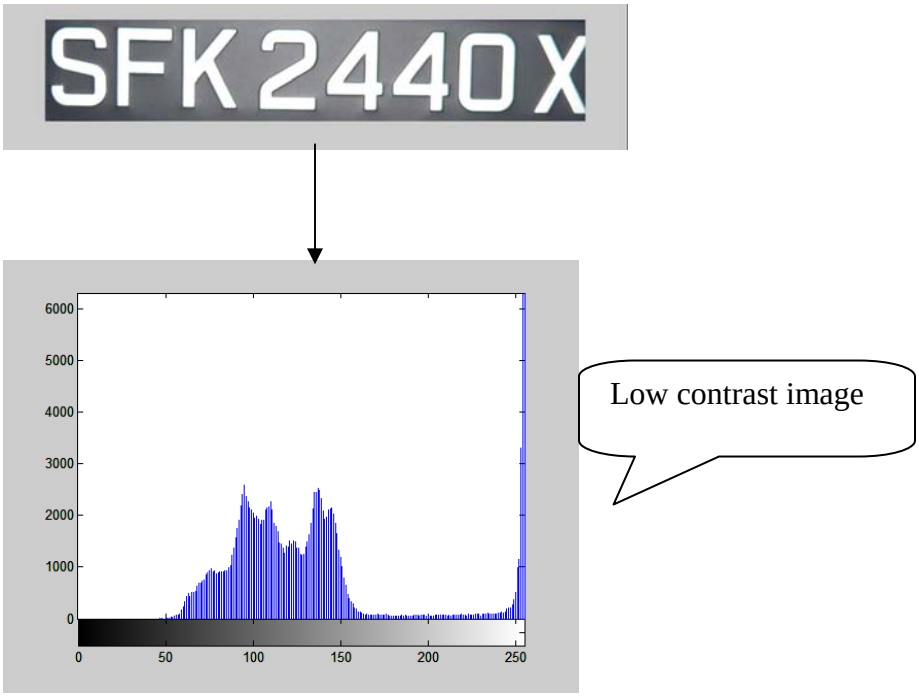
Where f = image
T = Threshold result.

In order to segment the image, we need to use T in the Matlab toolbox function im2bw as the value of threshold is in normalized range (0,1).

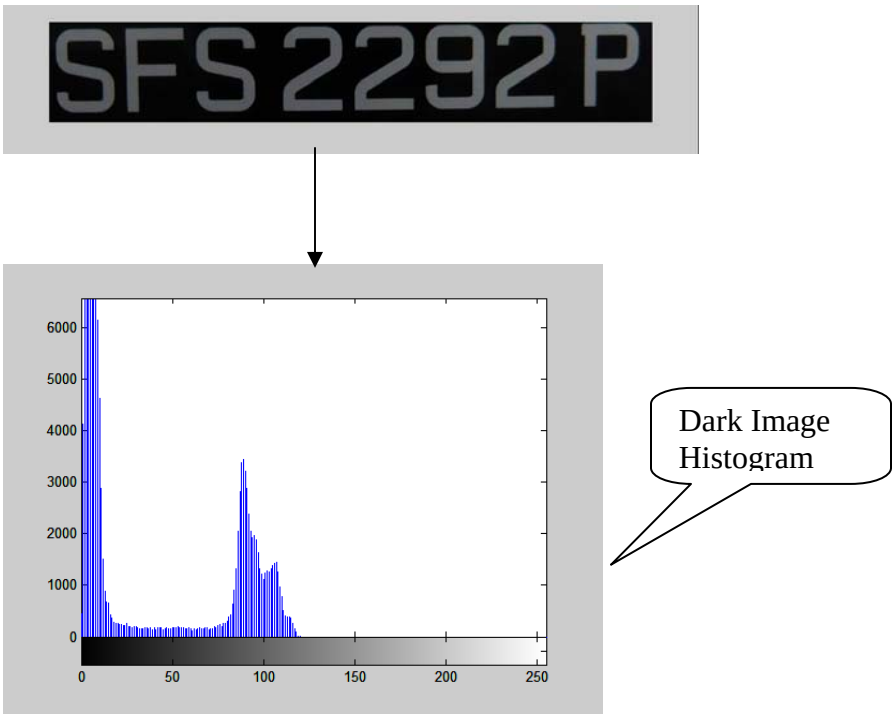
Images showing different kind of Histogram on Real Carplates



Graythresh value of the figure is 0.5098 * 255 = 129.99



Graythresh value of the figure is 0.7137 * 255 = 181.99



Graythresh value of the figure is 0.1922 * 255 = 49

Fig 13

5.3 Local Thresholding

This is a method whereby partitioning the image into sub-images and the value of threshold vale is determined from this sub-images.

5.4 Optimal Global Thresholding

This is a method whereby it approximate the threshold and produce in minimum error segmentation.
It depends on the approximation of the image histogram in which it used the function of the overall densities. The optimal threshold value can be determine if the form of densities determined.

5.5 Adaptive Thresholding

The vehicle number plate can be partially illustrated. This is a common reason why global thresholding fail. By using the adaptive thresholding, its can solve the disadvantages of the global thresholding as it computes the value of the threshold for every pixel separately using the neighborhood. If the histogram is bimodal, the value of the threshold will be taken in the middle of the bimodal. For other cases, in which the modes are overlapping,, the threshold will try to reduce the error of taking the background pixls as object pixel and vice versa.

6 Edge Detection

The initial steop in recognition of vehicle license plate is by detection of the number plate size. The challenge is to includes an algorithm that are able to detect the rectangle plate in the image. Lets define the rectangular plate as the horizontal and vertical edges. The horizontal and vertical edges of high density is normally caused by the contrast character from the number plate and this will eventually lead to detecting the wrong area.

Edge detection is the common method for finding the transistion between the two area based on the discontinuities in the intensity values.. Edge detection also base on the image edge information which is found by the relation of the pixel and its neighbour.

The magnitude of the vector representing ∇f is an importance quantity to the edge detection where ∇f is given by :

$$\nabla f = \text{mag}(\nabla f) = [G^2_x + G^2_y]^{0.5}$$

The vector for the gradient of the image f(x,y) at location(x,y) is given by:

$$\nabla f = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\delta f}{\delta x} \\ \frac{\delta f}{\delta y} \end{bmatrix}$$

For edge detection, the gradient vector for the direction play an important role. The threshold with a higher value in the image point is identify as the edge point. The gradient vector for the direction allow $\theta(x,y)$ to demonstrate the vector ∇f direction angle at (x,y) with respect to the x axis.

$$\theta(x,y) = \tan^{-1}\begin{bmatrix} \frac{Gy}{Gx} \end{bmatrix}$$

Sobel, Prewitt and Robert operators are the fews ways used to implement in digital form for the used of derivatives. Sobel dge operator provide advantages of both differencing and smoothing effect of the derivatives. It is rather sensitive to noise and emphasize more to the edge central section.
Sobel edge operator would create two images for the individual direction and to make sure the appearance and location of the edge in the image is still the same after combining the two images into one.

Vertical edge

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

Horizontal edge

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

Laplacian edge operator gave an estimation for the mathematical Laplacian. Zero crossing edge operator is maximum during the first derivatives and zero during the second derivative. Thus the aim of the edge detection is to locate the zero in the second derivatives.

$$\nabla f = f(x,y) = \frac{\delta^2 f}{\delta x^2} + \frac{\delta^2 f}{\delta y^2}$$

It will cause noise sensitivity and produce double edge as it is a second order derivative.
The feature detector is also known as zero crossing detector. It will stretch out on the closed contours. It will output to determine if the is pixel at the edge is lighter or in the darker side.
Therefore Sobel makes a good choice as Laplacian is not noise sensitive and create double edges.

6.1 IMAGE NOISE

Digital camera with long exposure time setting and high ISOs will produced images with lots of noise. Noise in the images is appears as the colour speckles whereby there should not be any.
The reason of noise contamination on the image is categorised as below:

- There will be not enough light source for proper exposure to activate in a low light area/ Therefore, we need longer time for the image sensor for collection of weak signal. In this circumstance, the electrical noise from the background will be higher than the signal

We will be enlarging the signal from the received light photons when we are using the digital camera with a higher ISO setting. From the amplification of the signal, the electrical noise in the background is also being amplified

6.2 Filtering

In this pre-processing stage, filtering process is used for blurring and for noise reduction and thus resulting a more sharpen image. Blurring is used in the pre-processing step which involved in removing and cleaning up of small patches and details from the image prior to object extraction, bridging of gaps in curves and lines. Next, blurring with liner/non liner filter is able to achieve noise reduction.
We can apply convention techniques such as softening and sharpening. In order to reduce the background noise, softening is often applied to the low pass filter and it will affect the image to become blurring.

High pass filter is used to determine and intensify the details in the image, but noise will be added during the process. High pass filter also used the convolution during the process. Example of Low Pass Filter / High Pass Filter masks is shown below:

1	2	1
2	4	2
1	2	1

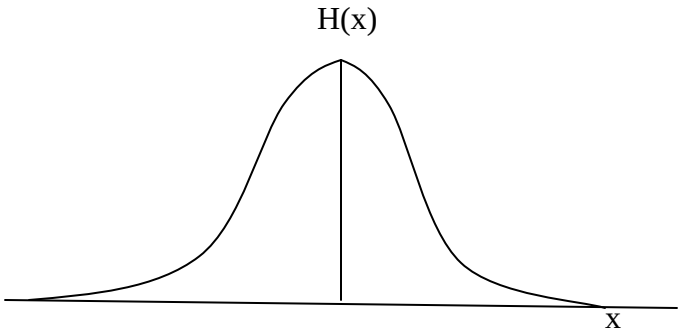


Fig 14

Figure showing corresponding mask for low pass filter.

0	-1	0
-1	4	-1
0	-1	0

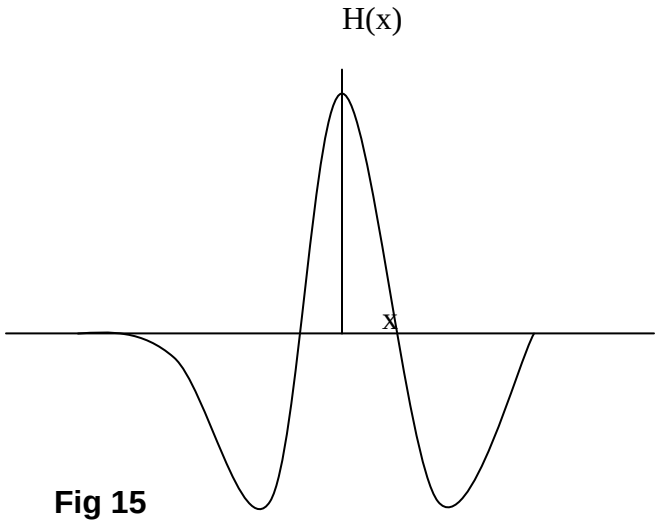


Fig 15

Figure showing corresponding mask for low pass and high pass filter.

6.3 Erosion

Erosion is one of the simplest method used for removing unwanted details from a binary image. There are also new method versions of erosion that work on grayscale images as well. The process of erosion basically reduces the objects size and getting rid of unwanted details by encoding the image with a structuring element of radius that is smaller than the object.

The characteristic of erosion for binary and grayscale images is as follows:

- For binary image, erosion will removes unwanted detail which is smaller than the structuring element.
- For grayscale image, the luminance and size of the bright object with dark background will be reduced. This is done so by taking the minimum of the neighborhood in which the structuring element passing thru the images.

The process is whereby the operator of erosion will take in two input data. Firstly is the image that need to be eroded and the secondly is the structuring element (coordinate points). The output of the erosion input image will be determined by the structuring element.

An example of 3 x 3 pixel structuring element is shown below:

0	1	0
1	1	1
0	1	0

6.4 Binary area open (Bwareaopen)

The MATLAB toolbox function provide a bwareaopen function in which it removes the connected component which have fewer than P pixel. Thus, it will reproduce another binary image. The syntax is as bellowed:

BW2 = bwareaopen(BW,P)

6.5 IMFILL (Flood-Fill Operations)

This function will perform flood-fill process on the grayscale and binary images. Imfill will change the pixels in the background (zeros) to pixel of foreground (ones) for the binary images. It will stop to fill once it reach the object boundary.
For the grayscale image, the process will fill up the holes by bringing the area of dark pixel to the surrounding brighter pixels.

6.6 IMCLEARBORDER

Imclearborder is the process whereby it suppress the connected light structures of the image border. Therefore, the process can remove any objects which is at the image border.
The imclearborder function for the connectivity is set to 4 for removal of the diagonal connectons.

6.7 FILTERING OF DIGITS

Now, we have managed to obtain the black and white image of the Vehicle License Plate. It has been cropped to a rectangular shape in which it enhances the algorithm to be more uniformed in the further stages.
The non-digits substance which appears in the image is caused by the noise (quantization that will transform to 'Black'), object or substance which is not digits/characters such as screws, sand, water droplet, frame lines, effects on JPEG compression.
By Filtering, we are able to remove or filter out the unwanted substances or noise that is not a character or digits. Lastly, the image is only left with characters and digits in which we are interested. The 2 stages for the algorithm is as follows:

1) Remove out the small objects or connected components.
2) Identify the frame line that is connected to the digits and separate it.

Identify and remove away the small connected objects

For this stage, we need to identify the connected components. The component can have a value of either 4-connected or 8-connected. In this algorithm, we use 8-connected (8 specify 8-connected objects). After the component has been labelled, they will obtain a unique number; The elements of **labels1 (stated in the algorithm)** contains integer values that will be greater than or equal to 0. The pixel of 0 represents the background and pixel of 1 will make up the first object, the pixel of 2 will label the second object, so on and so for. Below illustrate an example of filtering process.

For the above image, 29 connected components are found in the BW image. An algorithm is created whereby the threshold is determined by doing a statistic check.

Results obtain before filtering

numOfDigits1 =

29

Results of statistic check

total =

Columns 1 through 7

57968 58189 4 54626 1608 1 1

Columns 8 through 14

60964 56243 1 2 56526 7 2

Columns 15 through 21

2 1705 2 2 56419 12 1

Columns 22 through 28

7 56326 17 11 20 411 3

Columns 29 through 31

7 56326 8

Next, we have apply the bwareaopen (Image Processing Toolbox) whereby it will remove all the connected components from the binary image that have value less than P pixels, in which it will produce another binary image.
Therefore, components with less than 54626 is classify as non digits components and need to be taken away.

Results after filtering

7 IMAGE SEGMENTATION

Image segmentation plays an important and critical step that lead to the analysis of the processed image data. In order to extract and analyzed the object characteristic, the process need to partition the image into different parts that will have a strong correlation with the objects.
Segmentation process can be categorized into several parts. Firstly is the global knowledge of an image. The feature of the image is represented by a histogram. Secondly is the boundary-based segmentation. The process uses the edge detection to obtain the region contours and the objects will construct from the obtain contours. Lastly will be the edge-based segmentation.
For this project, we will be trying out first category segmentation method, which is by using threshold.

7.1 FEATURE EXTRACTION FROM DIGITAL IMAGE

The digital image description is depends on the external and internal representation. The color or texture of the image is basically the internal representation whereas the external representation is based on the characteristic of the shapes. The normalized character description is based on the external characteristics as we only work for properties on the shape of the character. The descriptor vector includes the characteristics as the number of lines, vertical or diagonal edges etc. The process of the feature extraction is to transform the bitmap data into a form of descriptor in which more suitable for computer.
If we classify the similar character into classes, the descriptor of the character from the same class is close to each other in the vector space. This will lead to a success in pattern recognition process.
For feature extraction, I have presents the algorithm, annotation and the image as the figure below:

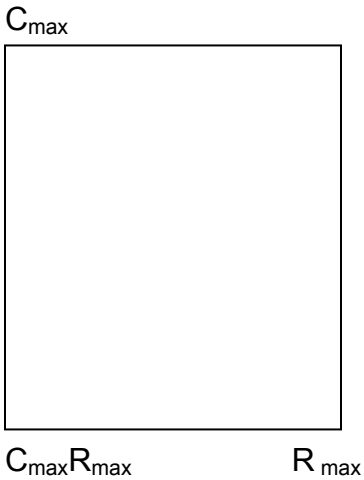


Fig 16

The algorithm below will represent how the extraction is being carried out and extracted figure is illustrated as below.

```
for loop = 1:numOfDigits2
    [r,c] = find(labels2==loop);
    offset = 5;
    rmin = min(r) - offset;
    rmax = max(r) + offset;
    cmin = min(c) - offset;
    cmax = max(c) + offset;
    digitsBW{loop} = imcrop(carplateBWFilter,[cmin rmin (cmax-cmin) (rmax -
rmin)]);
    figure, imshow(digitsBW{loop})
end
```

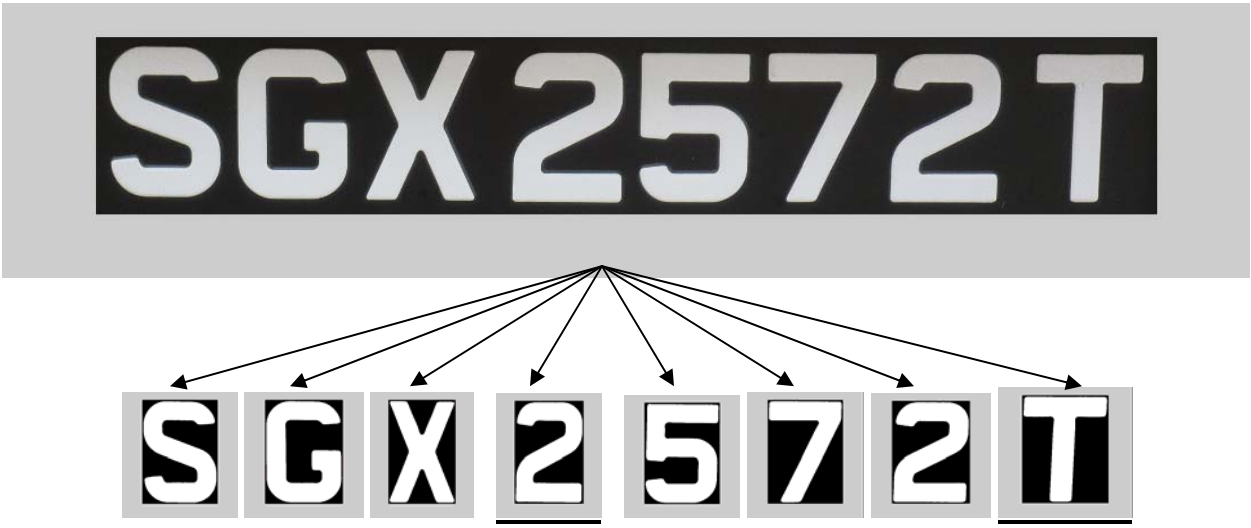


Fig 17

Database

It is a collection of information or data which it is being orderly organize, thus it can be accessed easily and updated. Database can be in the form of text, contents and images.
Database is needed to make sure that the image space can contained enough characters which have been extracted and the vehicle license plated number stored in the excel sheet for the purpose of comparison. The database would be enlarged in order to improve the accuracy and better chances of obtaining the correct result.
The class recognition will check if the computed ratio is correct. It will ignore the class if the image thresholding is too low. If the class has match correctly, it will be compare with data set in the database and provide an output if the image is recognized correctly.

8 Character Recognition

8.1 Normalization

In this phase, the extracted characters are resized to fit the characters into a window. For the project, each character is normalized to the size of (50x30) binary image and then follow by reshape to standard dimension before sending the data set to neural network for training.
It is very important to expnad the training database size for Neural Network. By increasing the database size, the efficiency and accuracy for the network will be improved.

A set of dataset will be attached in the Appendix 15.1 for reference

8.2 Introduction On Artificial Neural Network

Neural network is the interconnected group of artificial neuron which acquired mathematical model information to process based on the connectionist approach to computation. Neural network is an adaptive system in most cases as it is able to learn and attempt tasks on the given data for training. It is also an non linear statistical data modelling tools as they can access complex relationships of the inputs and outputs. Thus, it resemble human brain in two ways:

- Able to learn through acquiring of knowledge.
- Knowledge is stored in the inter neuron connections strength which is known as weights.

Neural network can be trained to perform certain function by making adjustment on the values of weights between elements. Neural network will be trained in order to make the input leads to a specific target output.
Multilayer perceptrons is apply to solve diverse problems and by training it in "supervises learning with highly popular algorithm is known as "error back-propagation algorithm. The error back propagation consists of passing two different layers of the network: a forward pass and backward pass. In forward pass, the input data is transfer to the sensory nodes of the neural network and then it will propagates the effect through the network. Finally, the input data will leads to an output, which is similar to the input vector that are used in the training and are similar to the presented input data. During the forward pass, the network weights are fixed. On the other hand, the network weight during the backward pass are adjusted accordingly to the error-correction rule. The response from the neural network is subtracted from the "target" response in which to produce error signal. The error signal will then propagate backward through the network in the opposite direction, thus known as "backpropagation"."Gradient Descent algorithm is the standard type of backpropagation whereby the weights of the network

is move along the negative of the gradient. The gradient is then compute for nonlinear multilayer networks.
Next, this are the general step when using backpropagation training function in the MATLAB toolbox:

- Training data will be assembled
- To create network object
- Network is being trained
- Network simulation respond the new data input.

In this project, I will be using Gradient Descent Backpropagation (Traingd) for training the neural network.

Traingd will take in this inputs

- Net = neural network
- Tr = Initial trainng record created by train
- trainV = Training data created by train
- valV = Validation data created by train
- testV = Test data created by train

Traingd will return :

- net = Trained Network
- TR = Training record of various values over each epoch

The figure below illustrate the multiplayer pecetron:

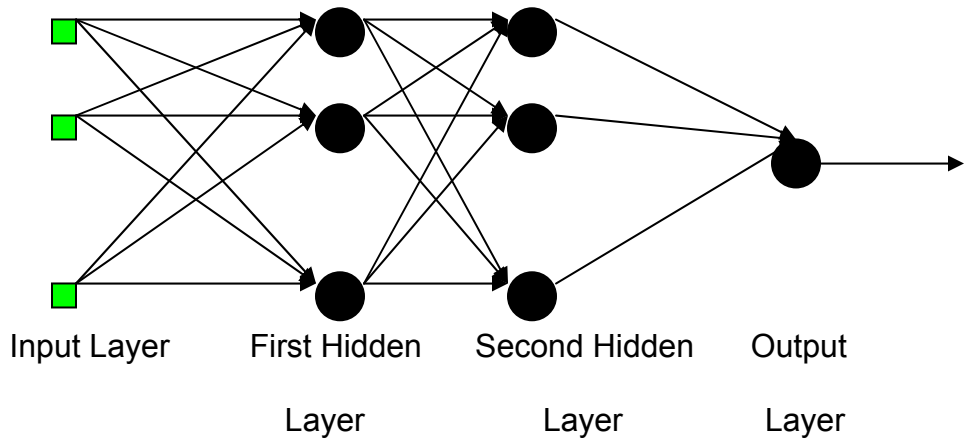
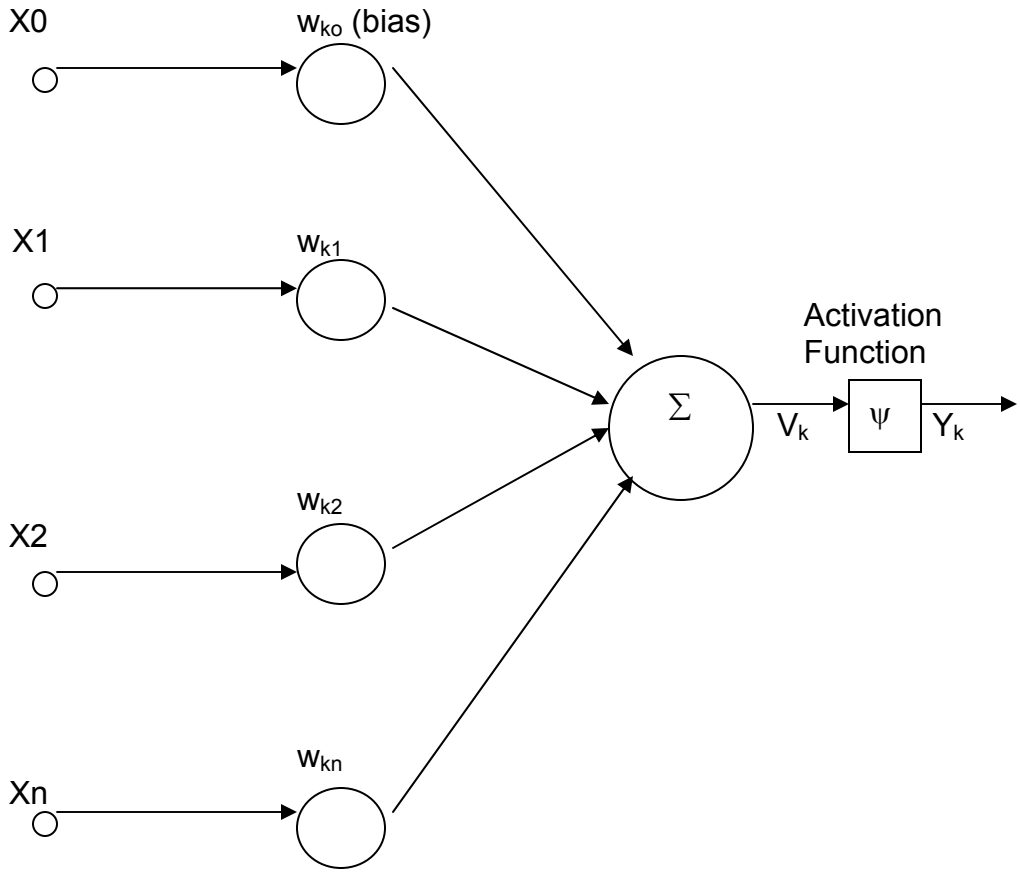


Fig 18

8.3 The Neuron

The neuron will consist of synapses set, an adder and an activation function. There is weight allocate to each synapse. The function of the adder will add the input signal and weight then by the neuron synapse. The function of the activation will control the amplitude of the neuron output.



Synaptic weights

Fig 19

Neuron mathematically can be determined by the equations:

- $\mu_K = \sum_{j=0}^{m} w_{kj} x_j$

- $V_k = \mu_k + b_k$

- $Y_k = \psi(\mu_k + b_k)$

The annotation of (X1…Xn) represents the input signal, w_{kn} represents the neuron synaptic weights, U_k is the adder output, Y_k represents the output and ψ_k represent the activation function.

Sigmoid function is one of the most common activation function used in neural network. It is a increasing function of S-shaped graph.

8.4 Training Modes

The learning results from the multiple presentation of the training set to the network. "Epoch" is the complete training set during the whole process of learning. The learning process will still be in progress unless an error signal hit the predestined minimum value. Thus, we need to shuffle the order of the presentation of the training examples between epochs.
There are two type of backpropagation learning for the given training set:

- The "sequential mode" referred as online, pattern mode and the weights will be updated after the training example
- The "batch mode" referred to weights will update after the training is presented to the network.

8.5 Teaching the Neural Network

There are two ways for learning the adaptive neural network. They are namely supervised and unsupervised.

- **Supervised learning**

An "external teacher" is available in which it is able to give the network with target response. The parameters of the network will be adjusted accordingly to the training vector and error signal. The adjustment is carried out with the target of making the network emulate the teacher. This type of "Supervised learning" is known as error correction

The figure below will illustrate Supervised Learning:

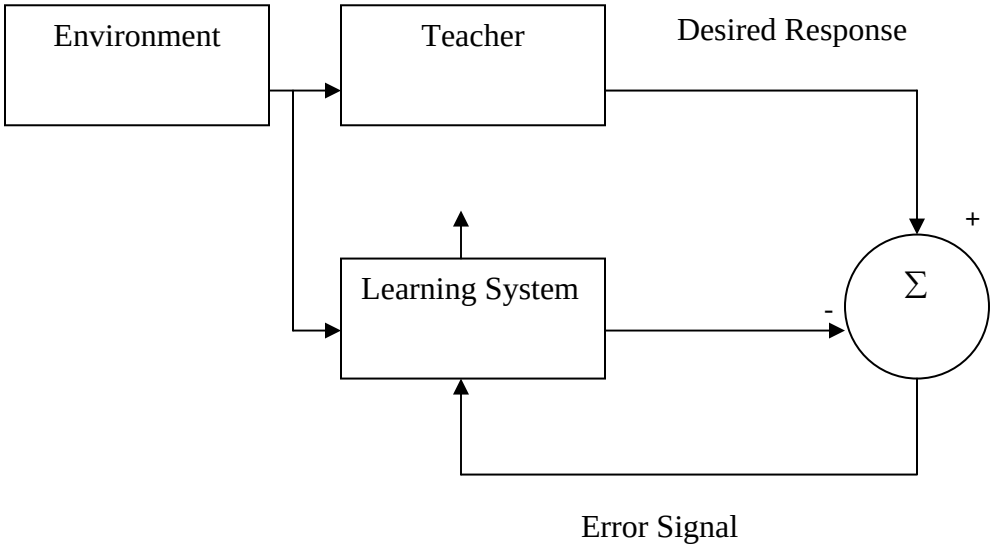


Fig 20

- **Unsupervised learning**

There will be no "external teacher" to overlook the learning process. Thus, no specific sample is to be learned by the neural network. Once the neural network has been trained to the statistical regularities, it will be able to develop and form internal representation for features encoding for the input. The figure below will illustrate unsupervised Learning:

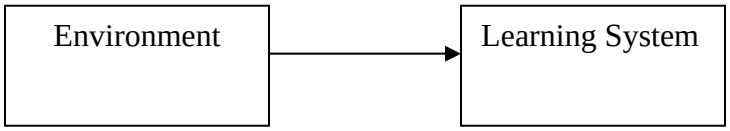


Fig 21

- **Pattern Recognition**

It is the process whereby the input data is assigned to a prescribed number of class. The neural network will perform the pattern recognition by going through a training session. The neural network will present the input data with the category in which the patterns belong to. Later, a new set of patterns will be present to network which has not seen before but still belong to the same population of pattern which is used to train the network. With the information which have been extracted from the training data, the neural network is still able to classify the class of the particular pattern.

9 DEVELOPMENT OF THE PROJECT SIMULATION

The project will begin by reading the objectives set at the initial stage of the report. Subsequently, the simulation of the specification will be studied.
Software for simulation will be developed in the modular form for testing and to troubleshoot more easier. The modules of development is listed in the three main parts:

- Extract individual digit from the car plate
- Recognize individual digit
- Check with database

Design Consideration

There will be 3 design considerations that will be involved in this project:

- Hardware Budget
- Hardware
- Software which will be used for implementing the project

Hardware Budget

A digital camera (Panasonic FX 30) will be used in capturing images of car license plate number/character. Therefore, a budget of around $300 is needed to purchase the carmea.

Specification of camera:
Sensor type - 7.2 million effective pixels
Movie clips - 640 x 480@30/10fps
320 x 240@30/10fps
848 x 480@30/10fps(16:9)
File formats - JPEG
DPOF
QuickTime Motion JPEG

Hardware

The required hardware that will be used for the project is basically a IBM ThinkPad T43 laptop.

Specification of laptop:

- Intel Pentium M 750 (1.86GHz, 2MB L2 Cache, 533MHz FSB)
- 14.0" SXGA (1400 x 1050) display
- 60GB, 7200RPM Hard Drive
- 512MB DDR2 SDRAM
- ATI X300 Graphics Card with 64MB RAM

Software to be used for implementing the project

MATLAB programming version 7.1 will be used as it is user friendly and image processing can be easily done too. MATLAB also give a high performance at numeric computation. Neural network is a function from vector to vector and interpolation function. Thus, MATLAB provides easy toolbox function for Neural Network to concentrate on the image dataset. We can also easily create the Graphical User Interface in the later part of the project rather than using the C programming.

10 ANALYSIS OF RESULT

Tests are conducted according to the modular form

Extracting of Individual Digits

Determine the angle of the Vehicle License Plate. It is generally important when capturing the vehicle image. For instance, the figure illustrate below lead to wrong recognition of the character

Recognition : SGFWF845A

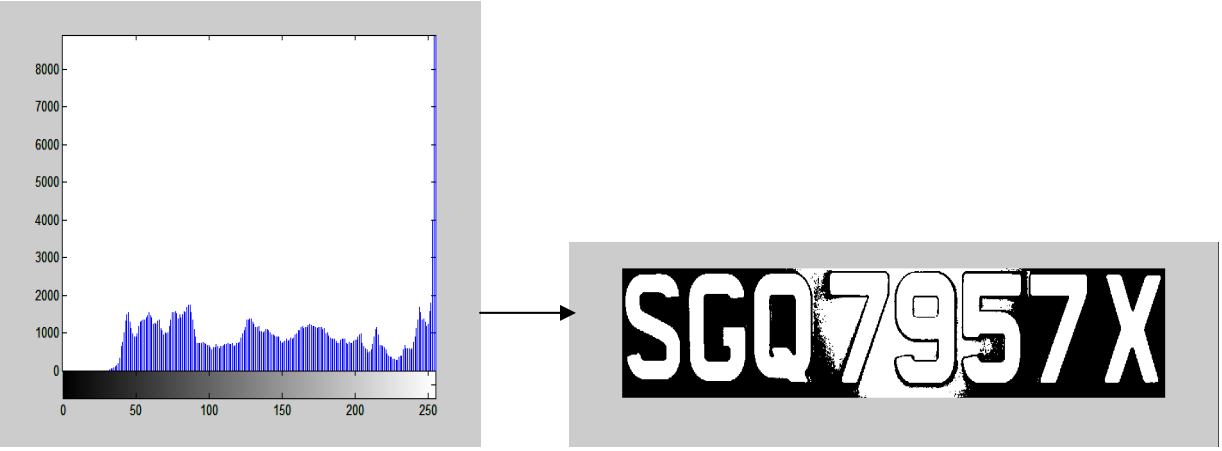
Recognition: SGX2572T

Fig 22

To improve in the cropping of image, we can improve on the accuracy of capturing of vehicle image. Next, we can also include an algorithm where we can change the image of the four coordinates to a standard rectangle size.

Vehicle Quantization and Equalization.

For some rare cases, such as very dark image, high contrast image, low contrast image, the binarized image do not allow to make the difference between the background and the digits. This will result fail recognition of the vehicle license plate. The figure illustrate a high contrast image which lead to wrong recognition.



Recognition : SGQM4R57X

Fig 23

To improve on the performance of the character recognition, we can make the difference between the digits and background inside the license plate. Equalization and quantization allow to obtain a gray scale image with improve contrast between digit and the background.

Checking and Verification of the Statistic

By using the MATLAB toolbox function (BWAREA), I am able to compute the objects area in the binary image. The algorithm below is able to compute the object area of the carplate.

```
Check Statistics
for loop = 1:1:numOfDigits1
   total(loop) = bwarea(find(labels1==loop))
end
```

For computing the carplate, the estimates object area is as below:

Total: (68241 68355 62302 68578 74191 47287 67763 44368)

In the midst of trying out other car plate, I have experience loosing out character when performing the extracting process. After much study the MATLAB toolbox syntax, I have managed to make adjustment on the value and apply the skill of binary area open (BWAREAOPEN) in which help to remove the small object too. Below illustrate a example of the scenario:

Total: (6962 5914 7758 5471 4133 6947 8183)

Morphologically open binary image (remove small objects)
carplateBWFilter = bwareaopen(carplateBW,4300);
figure,imshow(carplateBWFilter)

I have keep track of all the object area for the vehicle image and keep a copy in the Appendix15.6 for reference.

To obtain a more “cleaner” image , we can apply the technique of erosion which can remove irrelevant details from the binary image too.

NEURAL NETWORK RECOGNITION

Obtaining the input digit at the precedent step, the input digit will be compared to the images stored in the database. After interpolation, approximation algorithm, the system will produced an output to the closest digit stored in the database in which it was entered. Neural network is a function from vector to vector. Thus, Matlab is a good choice as it provide friendly user tools for Neural Network that allows to concentrate on the digit image database.

The recognition accuracy of the vehicle license plate is tabulated in the table. The second column on the left is the hidden layer size used in the testing process. The third column is the goal setting which need to achieve in the training phase. The fourth column shows the vehicle license plate which need to recognize. The fifth column shows the recognized characters of the vehicle license plate. Finally, the last column is the percentage of the vehicle license plate characters which were correctly recognized.

From the table, the accuracy of the vehicle license plate recognition system was tested by the performance on a 15 and 46 set of input images. The input images contain the zoom in vehicle license plate and images with head lamps on it. The success rate of the system is evaluated by the identification of the license plate and each of the individual characters.
it can clearly see that hidden layer of size 8 and 40 is insufficient as it produced poor accuracy and efficiency. As the size of the hidden layer increase and the goal is set lower, the recognition result shown a great improvement. The average recognition for the network hidden layer is as below:

Recognition Table

Hidden layer	Goal	Average Recognition
8	0.1	56.9%
16	0.1	68.57%
30	0.1	86.19%
40	0.1	88.9%
80	0.1	91.46%
150	0.1	93.48%
40	0.01	89.28%
80	0.01	92.12%
150	0.01	95.11%

From the table, the accuracy and efficiency will get better by using a larger size hidden layer. Sometimes, the system fail to recognize the image correctly. This is due to the lighting, distance is too far or too close when capturing the image . There are also some character susceptible to error compare to other characters. It can be due to the attributed to the similarity between different template. The solution to this is by redesigning the template characters in order to accentuate the similar characters.

Database

Upon testing the neural network, i discovered that it is of important in expanding of the alphanumeric database. The more image character stored in the database, I believe the accuracy of the network will improved.

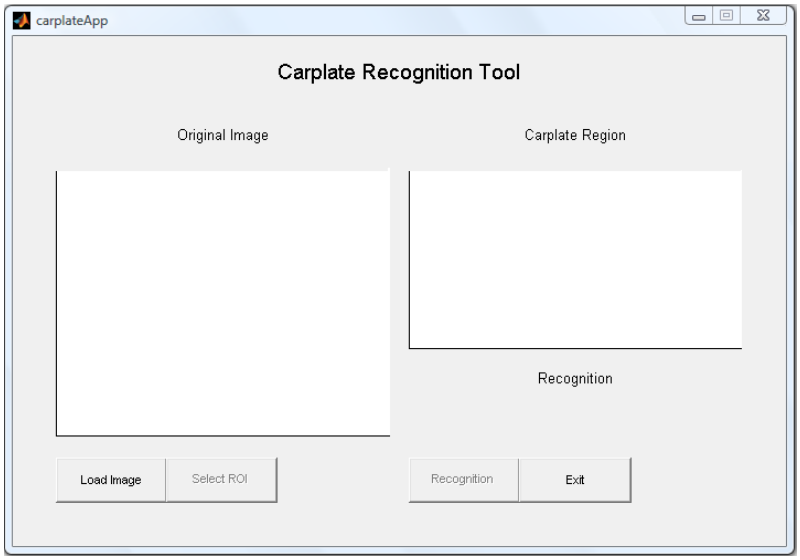
11 GRAPHICAL USER INTERFACE (GUI)

The graphical user interface allows people to interact with a computer. The GUI consists of graphical icons and special widgets. The icons are label with text to guide the user.

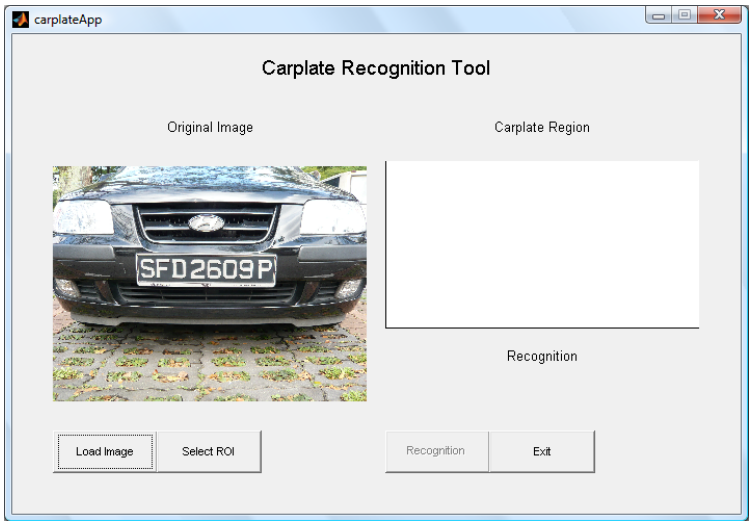
The Graphical User Interface for the vehicle license plate recognition is as shown below.

Graphical User Interface Specification:

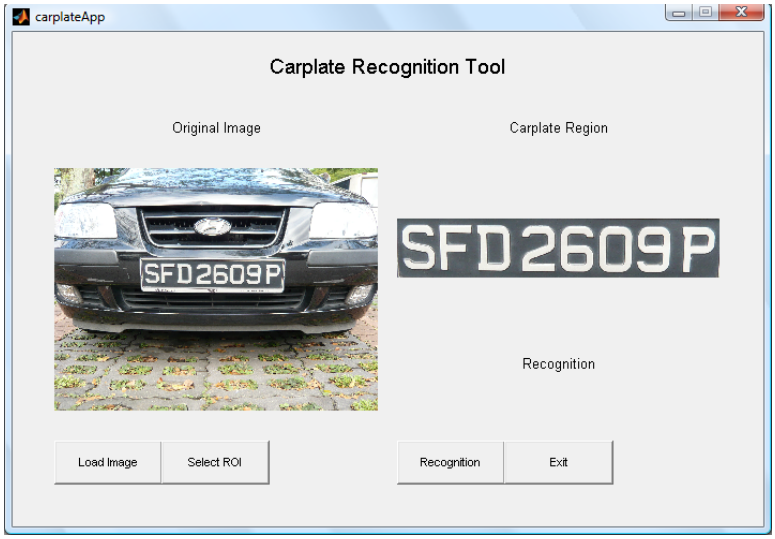
- Click on the “Load Image” icon. The function is to load vehicle image stored from the specific folder.



- The vehicle image will appear in the “Original Image box”.



- Click on the “Select ROI” to perform the manual cropping of the vehicle License plate. The cropped image will be transfer to the Car plate Region.



- Click on the “Recognition” icon, it will do a check with the database for this crop image and comparison will be done.
- The feedback of the result will be position under the “recognition”.

Fig 24

12 Critical Review and Reflection

The development of the project is considered quite successful although i still faced some problems during the progress of the project especially the three weeks in camp reservist. I have tried to defer but have been rejected. This period greatly slow down the progress of my project. I managed to solve the problem by doing more reading, research and with the help and understanding from the tutor. The problem encountered during the progress of the project include the selection of suitable method such as : sourcing of car images, methods on detection, method of segmentation and recognition of vehicle license plate character and writing of simulation program.

During the initial project and development stage, the problem encountered is the selection of software program. After doing much reading and research, I have chose MATLAB software as it is more easier in implementing it. Next, I also encountered problems in detection, segmentation, recognition of vehicle license plate characters. After doing much research and absorbing more knowledge into **MATLAB toolbox**, problems is able to resolved by using the suitable syntax and methods.

During the development and recognition of the vehicle license plate system, I faced difficulty in developing and training the neural network. After doing much testing , trial and error of using different size of hidden layer ,research of different method, training setting, the efficiency and accuracy of the network is greatly improved.

Project Plan

For developing the project, I have draft out the project schedule to follow up closely. I have listed several tasks in order to complement the schedule found in the Appendix.

Task1 Research (10 Sept 2007 to 17 November 2007)

- Research on various methods used for Vehicle License Plate Recognition
- Conversion of Images
- Image Thresholding
- Noise filtering
- Vehicle License Plate Detection
- Vehicle License Plate Extraction/Segmentation
- Vehicle License Plate Recognition

Task 2 Development (11 November to 23 December)

- Determine the value of pixel need for filtering
- Determine algorithm for plate detection
- Determine algorithm for extraction/segmentation
- Determine algorithm for plate recognition
- Determine the database and neural network used for the recognition system.

There is interconnected link between the research work and the designing and Implementation process. Thus, it is important to choose the type of model and syntax that are suitable for Matlab is taken into consideration

Task 3 Matlab Programming (20 November 2007 to 10 January 2007)

- Acquire basic knowledge of Matlab programming
- Acquire writing programs using Matlab in order to create the simulation software.
- Acquire main bulk of Matlab programming
- Acquire to choose the correct syntax which is suitable for the recognition process

Task 4 Construct Matlab software for simulation (1 January 2008 to 10 March 2008)

- Writing and create algorithm for extraction of vehicle license plate character
- Writing and create algorithm for training the network
- Writing and simulate the block by integrating all the written algorithm together
- Construct Graphical User Interface (GUI) which it will display the result of the algorithm with the original image.
- Analyzing and extract the carplateApp.m and trainNN.m from the Matlab Version 7 for editing.

Task 5 Testing and Fine Tuning (5 March 2008 to 1 April 2008)

- Fine tune on the training setting of neural network (epoch, goals, size)
- Fine tuning of the integrated block algorithm

Task 6 Reporting Writing (15 March 2008 to 16 April 2008)

- Allocate at least 4 weeks for writing the final report.

Skills Review

During the process of doing the final year project, I have acquired and master certain things. First of all is the planning and management of how a project is to be done. I have set quite a number of constraints and assumptions as the project title "Vehicle License Plate Recognition" contains a lot of possible cases. Secondly, I do not have any background and knowledge on MATLAB. With the listing of the constraints, I can managed my time more easily and concentrate more detail in the algorithm in which to be done for the recognition system and developing the database, thus this will improve the accuracy and proficiency of the system too. Study and research on Filtering, Thresholding, type of detection, Character extraction/segmentation , recognition , database and Graphical User Interface, the concept of recognition system really improve in which I do not know initially.
Thirdly, I have drafted out the procedure of report that need to be complete. I have seeks advice from my tutor before commencing it. Upon agreed, I need to followed the procedure schedule as close as possible. If any problems arises, the progress will significantly slowed down and more research work need to be done in order look for alternative solution.

A draft book has been used to note down the activities, problems encountered, data after running the simulation program. The draft book plays an important role as it help to keep track of the project progress and enhance me in writing the project report.

Furthermore, studies and research on the type of method used on the recognition system by means of related textbooks written by professors and obtain relevant information from surfing internet. Next, it is also important to acquire skills in analysing and understanding the correct information. In addition, my previous subject TZS 206 and relevant notes from TZS396 really helps me in picking up the idea of MATLAB software programming.
With the tutor great help and comments guide in TMA01, it provides me the guideline to improve the skills in project report writing.

13 Conclusion and recommendatins

The developoment of the Vehicle license Plate Recognition System is quite successful implemented using MATLAB version 7
For this project, I have discuss with my tutor and have listed out the process report that needed to be done.

- Read the color image into Matlab
- Manually crop the license carplate region from the color image
- Analyze the cropped image in its red, green blue frames
- Convert the image from RGB to HSV and analyze its Hue, Saturation and Value
- Image enhancement by using Histogram Equalization
- Image quantization by using thresholding
- Noise Reduction
- Extract each character and number from the image using segmentation techniques
- Training of the neural network
- Send the character and number to the neural network for recognition
- Results is to be displayed in Matlab
- A GUI will be developed after the techniques has been tested.

After much research, reading and mastering the skill of MATLAB, I am able to complete the above task and achieveing good results on the recognition. Next, I have also proceed to the auto-detection which I have modified the existing algorithm in the extractDigit.m. When running the main.m file, it is able to detect and recognize some of the zoom in car vehicle license plate but fail on the image of cars wih headlights.
For the future works and suggestion on improvements, these are the steps which are recommended:

- Modification is needed to be done on the offset of detecting the rectangular plate or by applying other technique to the system.
- The most critical problem is the training database size for Neural Network. By increasing the database size for training in future work, the efficiency and accuracy for the network will be improved
- We only due to the black and white image of the Vehicle license plate. For future implementation, we can use RGB to HSV or RGB to CMY method to deal with other type of color license plate.
- There are quite a number of possible case and due to lack of time, I did not tackle cases which capture frame from the video. We can incorporate by using GUI to MATLAB which will in line with a video camera.
- There should be improvement on the decision of the algorithm and ways to detect error. When the probability of recognition guess is correct but falls below the threshold, the recognition system should refuse to make the decision.

13 References

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- Lecture notes

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- Applying Neural Networks to Character Recognition
- Visual Character Recognition using Artificial Neural Networks
- Visl.technion.ac.il
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Software

- Matlab software version 7.1
  It is a very user friendly device as it will guide and explain to us on the specific toolbox in which we will be using.

APPENDIXES

15.1 Training Data Sets

Columns 1 through 18

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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Columns 55 through 66

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0

0 0 0 0 0 0 0 0 0 0 1 0
0 0 0 0 0 0 0 0 0 0 0 1

15.2 Email Communication With Tutor

3rd September

Hi Eng Yong
Can you have a look and do some revision?
Thanks
Chua Peng Huat

----- Forwarded Message ----
From: Bi Guoan (Assoc Prof) <EGBI@ntu.edu.sg>
To: Daniel Chua <daniel_chua_sg@yahoo.com>
Sent: Tuesday, September 4, 2007 9:23:58 AM
Subject: FW: TZ402 PPA

Hi, Daniel
Sorry for the delay of reply. I went through the proposal. The topic appears to be OK. However, more elaborated information should be provided. I put some comments in red in the report. In particular, the aims and background should have their relevant points. Also the student activities should be somehow related to the actual actions that are likely to be carried out during the project. It is not necessary that the student has to do according these activities, but the given information will reflect how much the student knows what he will do. Please ask the student to do a revision.

Regards

Bi Guoan
-----Original Message-----
From: Daniel Chua [mailto:daniel_chua_sg@yahoo.com]
Sent: Thursday, August 23, 2007 11:02 PM
To: Bi Guoan (Assoc Prof)
Cc: daniel_chua_sg@yahoo.com
Subject: TZ402 PPA

Hi Dr Bi
I am the tutor for the student and I am submitting the PPA for your approval.
Thanks
Chua Peng Huat

13th September

Can you please help to print a hardcopy and let me sign soonest?
Thanks

----- Forwarded Message ----
From: Bi Guoan (Assoc Prof) <EGBI@ntu.edu.sg>
To: daniel_chua_sg@yahoo.com
Sent: Friday, September 14, 2007 9:32:54 AM
Subject: FW: Fw: TZ402 PPA

Looks OK for this proposal. You can submit it to SIM.

-----Original Message-----
From: Daniel Chua [mailto:daniel_chua_sg@yahoo.com]
Sent: Tuesday, September 11, 2007 12:33 AM
To: Bi Guoan (Assoc Prof)
Subject: Re: Fw: TZ402 PPA

Hi Dr Bi
Revised.
Daniel

----- Original Message ----
From: Bi Guoan (Assoc Prof) <EGBI@ntu.edu.sg>
To: daniel_chua_sg@yahoo.com
Sent: Monday, September 10, 2007 8:42:10 AM
Subject: FW: Fw: TZ402 PPA

Hi
I made a few changes (in red) in the file. Please also clearly state if your system includes a database for storing the images and the identified numbers, which allows management of information. I also need the information for risk analysis. This is required although some project has no risk at all.

Bi Guoan

-----Original Message-----
From: Daniel Chua [mailto:daniel_chua_sg@yahoo.com]
Sent: Sunday, September 09, 2007 1:59 PM
To: Bi Guoan (Assoc Prof)
Subject: Fw: Fw: TZ402 PPA

Hi Dr Bi
We have amended the PPA. Can you please have a look again?
Thanks
Daniel

10th October (Important)

Hi
The steps look fine except that stage 8 should include a segmentation stage where the individual characters in the word are split out into separate objects for subsequent identification. 10) should be before 9) as the network needs to be trained first before using the network for recognition.
rgds
Daniel

----- Original Message ----
From: "wongengyong@yahoo.com" <wongengyong@yahoo.com>
To: Daniel Chua <daniel_chua_sg@yahoo.com>
Sent: Wednesday, October 10, 2007 12:50:30 PM
Subject: Process of report

Hi Sir,

I have list down the report steps that need to be
done. Can you help me check thru if it is ok. Thanks

1) Read the color image into MATLAB
2) Manually crop the license carplate region from the
color image
3) Analyze the cropped image in its Red, Green, Blue
frames
4) Convert the image from RGB to HSV and analyze its
Hue, Saturation
and Value

5) Image enhancement by using Histogram Equalization
6) Image quantization through thresholding
7) Noise reduction
8) Extract each character and number from the image
9) Send character and number to neural network for recognition
10) Training of the neural network using feed-forward network
11) Results will be displayed in MATLAB
12) A GUI will be displayed after the techniques has been tested.

Thanks and regards,
Wong

23rd Decemeber (Regarding Tma)

Hi
We could arrange to meet to review on your progress.
Your report writing is ok so far but you need to note
the structure of your report
--- wongengyong@yahoo.com wrote:
Hi Sir,

Just to check will you schedule a meet up to review
on
my tma 1?
Really need your guidance and help in order to
improve
my report writing.

Rgds,
Wong

5th Jan 08 (National Reservist Deferment)

Dear Mr Wong,

We have forwarded your email to the Student Records Department.

Regards,
Crystal Auyong
Asst. Officer, Student Relations

SIM University
Tel: 6248 9111

On 2008-01-04, 13:57, wongengyong@yahoo.com wrote:> Attention to Officer In Charge,

I would to request for a letter from Unisim with regards to deferment or early release for reservist due to my final year project. (Submission date is april 2008).

As my reservist starts on the 14 January 2008, is it possible for me to receive the letter by next week or alternatively i can go to Unisim and collect it.

> Thanks and Regards,
> Wong Eng Yong
> PI : U1260238

14 January 08 (Report progress of project to tutor)

Hi Eng Yong
Thanks for the update. Do not be too unduly concerned with the due date. Your work flow looks fine.
Thanks
Daniel
--- wongengyong@yahoo.com wrote:

Hi Sir,
Here is the update of my project progress:

1) Read the color image into MATLAB (Done)
2) Manually crop the license carplate region from the color image (Done)

3) Analyze the cropped image in its Red, Green, Blue frames
4) Convert the image from RGB to HSV and analyze its Hue, Saturation and Value

There are some constraints which i set in the report.
I will emphasize mostly on the black blackground and white character carplate. For point 3 and 4, i will carry out if i complete the whole project.

5) Image enhancement by using Histogram

Equalization
6) Image quantization through thresholding
For point 5 and 6, i try to plot histogram and test whether the image is properly exposed.

7) Noise reduction (Done). To get rid of the unwanted noise in order to obtain the clean image.

8) Extract each character and number from the image using segmentation techniques (Done)

Right now, i am on the midst on analysing developing database and neural network using feed forward network. follow by GUI.

Some queries to clarify,
This are the constraints which i set earlier on due to
limited time that we possess and dealing with image vision software, some constraints are as below:

i) Image taken only when vehicle is stationary
ii) Captured image of vehicle at fixed distance.
iii) Captured image of vehicle at fixed angle
iv) There will be no motion capture image

Can i just take the stationary car in the carpark instead at the gantry?

I will be on reservist on 14 Jan 08 to 5th Feb 08. I am afraid this will afttect my progress and have submitted my letter to the mindef to request for early out pro or deferment but still no answer yet. I will bring in all the reading materials to study in case the request is being rejected. Hope for your kind understanding.

Happy new year,
Rgds,
Wong

--- Daniel Chua <daniel_chua_sg@yahoo.com> wrote:

Hi
The steps look fine except that stage 8 should include a segmentation stage where the individual characters in the word are split out into separate objects for subsequent identification. 10) should be
before 9) as the network needs to be trained first before using the network for recognition.
rgds
Daniel

----- Original Message ----
From: "wongengyong@yahoo.com" <wongengyong@yahoo.com>
To: Daniel Chua <daniel_chua_sg@yahoo.com>
Sent: Wednesday, October 10, 2007 12:50:30 PM
Subject: Process of report

Hi Sir,

I have list down the report steps that need to be done. Can you help me check thru if it is ok.
Thanks

1) Read the color image into MATLAB
2) Manually crop the license carplate region from the color image
3) Analyze the cropped image in its Red, Green, Blue frames
4) Convert the image from RGB to HSV and analyze its Hue, Saturation and Value
5) Image enhancement by using Histogram Equalization
6) Image quantization through thresholding
7) Noise reduction
8) Extract each character and number from the image
9) Send character and number to neural network for recognition
10) Training of the neural network using feed-forward network
11) Results will be displayed in MATLAB

12) A GUI will be displayed after the techniques has been tested.

11th February 08

Hi Eng Yong
Perhaps we can discuss when you are more ready. At least you should have some basic understanding of neural networks.
rgds
--- wongengyong@yahoo.com wrote:

Hi Sir,

Happy new year to you. I had just finished my reservist on the 2nd of February...hardly got time to hands on the algorithm.
Developing database is still in progress as i try to take more different type of character designs and concurrently, trying to digest on the training of neural network.
Do we need to meet up and discuss in details?
Rgds,
Wong

18th February 08

Hi
Yes that would be good. You should start with the assumption that there is no motion first to test that the method can work first
rgds
--- wongengyong@yahoo.com wrote:

Hi Sir,

I need to check if the system need to capture the vehicle in motin as this project covers quie alot of possible cases. For the initial report, i have set a constraints that no motion capture image will be taken into consideraton amd i can concentrate more time in trying out neural network algo and making the project more systematic and manageable.

5th March 08

hi
thanks for the update.
what is the sample size that you use to train the network?
--- wongengyong@yahoo.com wrote:

Hi Sir,

Update to you on the progress of the project.

Take up quite some time to do reading and trying out the neural network.
Face problem when training, expanding database, duration of training...
Able to train now and able to recognixe some carplate but result still not good enough...now in the progress to try out other method in order to improve the efficiency and accuracy of nn.

10th March 08

Hi
Lets see the progress before we see if the motion part can be investigated
rgds
--- wongengyong@yahoo.com wrote:

Hi Sir,

Thanks for the reply. I extracted the numbers and characters from the carplate to train the network. It will be more realistic and accurate too. I roughly Use the size of 17 X 34. Maybe the size is too big which cause the network to be unstable. Do you have a better suggestions? I will trial and error to reduce down the size accordingly and test the network again.
I will document it down and will include it in the report.
Next, i will move on the the GUI part if the network is successful.

Sir, will i be penalize if i can't able to tackle
the motion part cos there are so much possible cases in
these project.
Rgds,Wong

16th March 08
Hi
Thanks for the update.
How many layers are you using for the neural network?

--- wongengyong@yahoo.com wrote:

Hi Sir,

I have improve the network by reducing down the
size.(tial and error). I have try out on quite a
number of car pictures but able to achieve roughly
65 to 70% accuracy. Due to light contrast, reflection,
detented car plates, structure of carplates and
designs of characters. Now i am in the midst of
doing the GUI and improving the neural network to achieve
better accuracy.

Rgds,
Wong
4th April 08

You should have a section to compare the algorithms
that you have investigated in the literature review
chapter maybe in the form of a comparison table.

--- wongengyong@yahoo.com wrote:

Hi Sir,

Here is the latest update of my project progress:

1) Read the color image into MATLAB (Done)
2) Manually crop the license carplate region from
the color image (Done)
3) Analyze the cropped image in its Red, Green,
Blue frames
4) Convert the image from RGB to HSV and analyze
its Hue, Saturation and Value
There are some constraints which i set in the
report. I will emphasize mostly on the black blackground

and white character carplate. For point 3 and 4, i
will carry out if i complete the whole project.
5) Image enhancement by using Histogram Equalization
6) Image quantization through thresholding
For point 5 and 6, i try to plot histogram and
Test whether the image is properly exposed.
7) Noise reduction (Done). To get rid of the
unwanted noise in order to obtain the clean image.
8) Extract each character and number from the image
(Done)
9)Building database and neural network using feed
forward network. (Done) Still can further improve
on neural network and database.

Face problem when expanding the database. Training
curves unable to reach the goal.Getting to try more different size.

10) Graphical User interface. (Done) Able to
illustrate display on image with correct read back.
Right now, i am compiling all the data result and working out with the report writing.
In progress improvement on algo (Besides the assumption which i have set in tma1)
1) I am also trying to improve the algorithm by
auto
detecting the vehicle license plate instead of doing
manual cropping. (stationary car image)
2) Detect other type of vehicle number plate
besides
the assumption i set in the tma01.
Example : SGX 1234T (Black and white done)
Now, I am trying to do detection on
SGX
1234T
Sir, please feedback on my progress. Thanks

sincerely,
Wong

15.3 Algorithm on carplateApp.m

```
function varargout = carplateApp(varargin)

%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help carplateApp



% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @carplateApp_OpeningFcn, ...
                   'gui_OutputFcn',  @carplateApp_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before carplateApp is made visible.
function carplateApp_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to carplateApp (see VARARGIN)

% Choose default command line output for carplateApp
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

% UIWAIT makes carplateApp wait for user response (see UIRESUME)
% uiwait(handles.figure1);
```

```
% --- Outputs from this function are returned to the command line.
function varargout = carplateApp_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;


% --- Executes on button press in pbLoadImage.
function pbLoadImage_Callback(hObject, eventdata, handles)
% hObject    handle to pbLoadImage (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Read in image file
[FileName,PathName] = uigetfile('*.jpg','Select the Image file');
carRGB = imread([PathName '\' FileName]);

handles.carRGB = carRGB ;
% Update handles structure
guidata(hObject, handles);

axes(handles.axes1)
imshow(carRGB) % Display

set(handles.pbSelectROI,'enable','on')
set(handles.pbRecognition,'enable','off')

cla(handles.axes2)
set(handles.txtShow,'string','')

% --- Executes on button press in pbSelectROI.
function pbSelectROI_Callback(hObject, eventdata, handles)
% hObject    handle to pbSelectROI (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

carRGB = handles.carRGB;
axes(handles.axes1)
set(handles.axes1,'Visible','on')
[carplateRGB carplateRect] = imcrop(carRGB);

handles.carplateRGB = carplateRGB;
% Update handles structure
guidata(hObject, handles);

axes(handles.axes2)
imshow(carplateRGB) % Display

set(handles.pbRecognition,'enable','on')

% --- Executes on button press in pbRecognition.
```

```
function pbRecognition_Callback(hObject, eventdata, handles)
% hObject    handle to pbRecognition (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

carplateRGB = handles.carplateRGB;

% Convert from RGB to Grayscale
carplateI = rgb2gray(carplateRGB);

% Determine global image threshold using Otsu's method
level = graythresh(carplateI);

% Convert image to binary image, based on threshold
carplateBW = im2bw(carplateI,level);
[labels1,numOfDigits1] = bwlabel(carplateBW,8);

% Morphologically open binary image (remove small objects)
carplateBWFilter = bwareaopen(carplateBW,9000);
[labels2,numOfDigits2] = bwlabel(carplateBWFilter,8);

for loop = 1:numOfDigits2
    [r,c] = find(labels2==loop);
    offset = 5;
    rmin = min(r) - offset;
    rmax = max(r) + offset;
    cmin = min(c) - offset;
    cmax = max(c) + offset;
    digitsBW{loop} = imcrop(carplateBWFilter,[cmin rmin (cmax-cmin) (rmax -
rmin)]);
end

% Load trained neural network
load nnWong2

% Load size that was used during training of neural network
digitRow = 50;
digitCol = 30;

numofDigits = size(digitsBW,2);

for loop=1:numofDigits
    getDigit = reshape(imresize(digitsBW{loop},[digitRow digitCol]),[1
digitRow*digitCol])';
    simDigit = sim(net,{getDigit});
    [dummy recogniseDigitIndex] = max(simDigit{:});
    recogniseDigit{loop} = lookupDigitV2(recogniseDigitIndex);
end

set(handles.txtShow,'string',char(recogniseDigit)');

% Check with excel database
[numCP, txtCP] = xlsread('CPdatabase updated.xls', 'Authorise');
txtCP = upper(txtCP);

if isempty(strmatch(char(recogniseDigit)',txtCP))
    set(handles.txtStatus,'String','Access Denied')
```

```
else
    set(handles.txtStatus,'String','Access Granted')
end

% --- Executes on button press in pbExit.
function pbExit_Callback(hObject, eventdata, handles)
% hObject    handle to pbExit (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close


% --- Executes during object creation, after setting all properties.
function pbRecognition_CreateFcn(hObject, eventdata, handles)
% hObject    handle to pbRecognition (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called


% --- Executes during object creation, after setting all properties.
function pbLoadImage_CreateFcn(hObject, eventdata, handles)
% hObject    handle to pbLoadImage (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called
```

15.3a Algorithm on createAlphanum.m

```
clear all
load alphanumeric

digitRow = 50;
digitCol = 30;

alpha2_a = reshape(imresize(alpha_a,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_b = reshape(imresize(alpha_b,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_b1 = reshape(imresize(alpha_b1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_b2 = reshape(imresize(alpha_b2,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_c = reshape(imresize(alpha_c,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_c1 = reshape(imresize(alpha_c1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_d = reshape(imresize(alpha_d,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_d1 = reshape(imresize(alpha_d1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_e = reshape(imresize(alpha_e,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_e1 = reshape(imresize(alpha_e1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_e2= reshape(imresize(alpha_e2,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_e3 = reshape(imresize(alpha_e3,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_e4 = reshape(imresize(alpha_e4,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_f = reshape(imresize(alpha_f,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_f1 = reshape(imresize(alpha_f1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_f2 = reshape(imresize(alpha_f2,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_f3 = reshape(imresize(alpha_f3,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_g = reshape(imresize(alpha_g,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_g1 = reshape(imresize(alpha_g1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_g2 = reshape(imresize(alpha_g2,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_h = reshape(imresize(alpha_h,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_h1 = reshape(imresize(alpha_h1,[digitRow digitCol]),[1
digitRow*digitCol])';
```

```
alpha2_j = reshape(imresize(alpha_j,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_j1 = reshape(imresize(alpha_j1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_k = reshape(imresize(alpha_k,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_l = reshape(imresize(alpha_l,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_m = reshape(imresize(alpha_m,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_m1 = reshape(imresize(alpha_m1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_m2 = reshape(imresize(alpha_m2,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_n = reshape(imresize(alpha_n,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_p = reshape(imresize(alpha_p,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_p1 = reshape(imresize(alpha_p1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_q = reshape(imresize(alpha_q,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_r = reshape(imresize(alpha_r,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_r1 = reshape(imresize(alpha_r1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_r2 = reshape(imresize(alpha_r2,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_s = reshape(imresize(alpha_s,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_s1 = reshape(imresize(alpha_s1,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_t = reshape(imresize(alpha_t,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_u = reshape(imresize(alpha_u,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_v = reshape(imresize(alpha_v,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_w = reshape(imresize(alpha_w,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_x = reshape(imresize(alpha_x,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_y = reshape(imresize(alpha_y,[digitRow digitCol]),[1
digitRow*digitCol])';
alpha2_z = reshape(imresize(alpha_z,[digitRow digitCol]),[1
digitRow*digitCol])';

num2_0 = reshape(imresize(num_0,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_1 = reshape(imresize(num_1,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_1a = reshape(imresize(num_1a,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_1b = reshape(imresize(num_1b,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_2 = reshape(imresize(num_2,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_2a = reshape(imresize(num_2a,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_3 = reshape(imresize(num_3,[digitRow digitCol]),[1 digitRow*digitCol])';
```

```
num2_3a = reshape(imresize(num_3a,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_4 = reshape(imresize(num_4,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_5 = reshape(imresize(num_5,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_5a = reshape(imresize(num_5a,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_6 = reshape(imresize(num_6,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_7 = reshape(imresize(num_7,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_7a = reshape(imresize(num_7a,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_7b = reshape(imresize(num_7b,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_8 = reshape(imresize(num_8,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_8a = reshape(imresize(num_8a,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_8b = reshape(imresize(num_8b,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_8c = reshape(imresize(num_8c,[digitRow digitCol]),[1
digitRow*digitCol])';
num2_9 = reshape(imresize(num_9,[digitRow digitCol]),[1 digitRow*digitCol])';
num2_9a = reshape(imresize(num_9a,[digitRow digitCol]),[1
digitRow*digitCol])';
%%
alphanum = [alpha2_a, alpha2_b, alpha2_b1, alpha2_b2, alpha2_c,
alpha2_c1,alpha2_d, alpha2_d1, alpha2_e,...
    alpha2_e1, alpha2_e2, alpha2_e3, alpha2_e4, alpha2_f, alpha2_f1,
alpha2_f2, alpha2_f3, alpha2_g, alpha2_g1, alpha2_g2, alpha2_h,...
    alpha2_h1, alpha2_j, alpha2_j1, alpha2_k, alpha2_l, alpha2_m, alpha2_m1,
alpha2_m2, alpha2_n, alpha2_p, alpha2_p1,...
    alpha2_q, alpha2_r, alpha2_r1, alpha2_r2, alpha2_s, alpha2_s1, alpha2_t,
alpha2_u, alpha2_v, alpha2_w, alpha2_x, alpha2_y,...
    alpha2_z, num2_0, num2_1, num2_1a, num2_1b, num2_2, num2_2a, num2_3,
num2_3a, num2_4, num2_5, num2_5a, num2_6, num2_7,...
    num2_7a, num2_7b, num2_8, num2_8a, num2_8b, num2_8c, num2_9, num2_9a];


target = eye(66);

save alphanumeric
disp('Done!')
```

15.3b Algorithm on extactdigit.m

```
%% Read in image file
% carRGB = imread('E:\Personal\wongey\tk\pics\P1030124.JPG');
[FileName,PathName] = uigetfile('*.jpg','Select the Image file')
carRGB = imread([PathName '\' FileName]);
figure,imshow(carRGB) % Display

%%
carR = carRGB(:,:,1); %Extract red frame
figure,imshow(carR)
carG = carRGB(:,:,2); %Extract Green frame
figure,imshow(carG)
carB = carRGB(:,:,3); %Extract Blue frame
figure,imshow(carB)

%% Manually select carplate region
[carplateRGB carplateRect] = imcrop(carRGB);
figure,imshow(carplateRGB) % Display

% figure,imshow(carplateRGB) % Display

%% Convert from RGB to Grayscale
carplateI = rgb2gray(carplateRGB);
figure,imshow(carplateI)% Display
figure,imhist(carplateI)
% figure,imshow(carplateI) % Display
% figure,imhist(carplateI) % Display

%% Test threshold
% figure,imshow(carplateI > 125)

%% Determine global image threshold using Otsu's method
level = graythresh(carplateI)

%% Convert image to binary image, based on threshold
carplateBW = im2bw(carplateI,level);
figure,imshow(carplateBW) % Display

[labels1,numOfDigits1] = bwlabel(carplateBW,8);

%% Check Statistics
for loop = 1:1:numOfDigits1
    total(loop) = bwarea(find(labels1==loop))
end

%% Morphologically open binary image (remove small objects)
carplateBWFilter = bwareaopen(carplateBW,3300);
figure,imshow(carplateBWFilter)

[labels2,numOfDigits2] = bwlabel(carplateBWFilter,8);
```

```
figure,image(labels2)

%%
for loop = 1:numOfDigits2
    [r,c] = find(labels2==loop);
    offset = 5;
    rmin = min(r) - offset;
    rmax = max(r) + offset;
    cmin = min(c) - offset;
    cmax = max(c) + offset;
    digitsBW{loop} = imcrop(carplateBWFilter,[cmin rmin (cmax-cmin) (rmax -
rmin)]);
    figure, imshow(digitsBW{loop})
end
```

15.3c Algorithm on lookupDigitV2.m

```
function output = lookupDigitV2(input)

switch input
    case 1
        output = 'A';
    case 2
        output = 'B';
    case 3
        output = 'B';
    case 4
        output = 'B';
    case 5
        output = 'C';
    case 6
        output = 'C';
    case 7
        output = 'D';
    case 8
        output = 'D';
    case 9
        output = 'E';
    case 10
        output = 'E';
    case 11
        output = 'E';
    case 12
        output = 'E';
    case 13
        output = 'E';
    case 14
        output = 'F';
    case 15
        output = 'F';
    case 16
        output = 'F';
    case 17
        output = 'F';
    case 18
        output = 'G';
    case 19
        output = 'G';
    case 20
        output = 'G';
    case 21
        output = 'H';
    case 22
        output = 'H';
    case 23
        output = 'J';
```

```
case 24
    output = 'J';
case 25
    output = 'K';
case 26
    output = 'L';
case 27
    output = 'M';
case 28
    output = 'M';
case 29
    output = 'M';
case 30
    output = 'N';
case 31
    output = 'P';
case 32
    output = 'P';
case 33
    output = 'Q';
case 34
    output = 'R';
case 35
    output = 'R';
case 36
    output = 'R';
case 37
    output = 'S';
case 38
    output = 'S';
case 39
    output = 'T';
case 40
    output = 'U';
case 41
    output = 'V';
case 42
    output = 'W';
case 43
    output = 'X';
case 44
    output = 'Y';
case 45
    output = 'Z';
case 46
    output = '0';
case 47
    output = '1';
case 48
    output = '1';
case 49
    output = '1';
case 50
    output = '2';
case 51
    output = '2';
case 52
```

```
    output = '3';
case 53
    output = '3';
case 54
    output = '4';
case 55
    output = '5';
case 56
    output = '5';
case 57
    output = '6';
case 58
    output = '7';
case 59
    output = '7';
case 60
    output = '7';
case 61
    output = '8';
case 62
    output = '8';
case 63
    output = '8';
case 64
    output = '8';
case 65
    output = '9';
case 66
    output = '9';
end
```

15.3d Algorithm on simNN.m

```
load nnWong2

digitRow = 50;
digitCol = 30;

numofDigits = size(digitsBW,2)

for loop=1:numofDigits
    getDigit = reshape(imresize(digitsBW{loop},[digitRow digitCol]),[1
digitRow*digitCol]);
    simDigit = sim(net,{getDigit'})
    [dummy recogniseDigitIndex] = max(simDigit{:});
    recogniseDigit{loop} = lookupDigitV2(recogniseDigitIndex);
end

msgbox(char(recogniseDigit)')
```

15.3e Algorithm on trainNN.m

```
clear all
load alphanumeric

alphanum = double(alphanum);
target = double(target);

[R,Q] = size(alphanum);
[S2,Q] = size(target);

S1 = (digitRow*digitCol)/10;
% nn2
% net = newff(minmax(alphanum),[S1 S2],{'logsig' 'logsig'},'traingd');
% nn3
net = newff(minmax(alphanum),[S1 S2],{'logsig' 'logsig'},'traingd');
net.LW{2,1} = net.LW{2,1}*0.01;
net.b{2} = net.b{2}*0.01;

net.performFcn = 'sse';        % Sum-Squared Error performance function
net.trainParam.goal = 0.01;     % Sum-squared error goal.
net.trainParam.show = 1000;      % Frequency of progress displays (in
epochs).
net.trainParam.epochs = 1000000;  % Maximum number of epochs to train.
net.trainParam.mc = 0.99;      % Momentum constant.

%%
P = alphanum;
T = target;
[net,tr] = train(net,P,T);
```

```
%%
save nnWong2 net tr
```

15.3f Algorithm on extractDigit.m(auto)

```
%% Read in image file
% carRGB = imread('E:\Personal\wongey\tk\pics\P1030124.JPG');
[FileName,PathName] = uigetfile('*.jpg','Select the Image file')
carRGB = imread([PathName '\' FileName]);
figure,imshow(carRGB) % Display

%%
% carR = carRGB(:,:,1); %Extract red frame
% figure,imshow(carR)
% carG = carRGB(:,:,2); %Extract Green frame
% figure,imshow(carG)
% carB = carRGB(:,:,3); %Extract Blue frame
% figure,imshow(carB)

%% Manually select carplate region
% [carplateRGB carplateRect] = imcrop(carRGB);
% figure,imshow(carplateRGB) % Display

%% Automatically select carplate region
carI = rgb2gray(carRGB);
level1 = graythresh(carI);

carBW = im2bw(carI,level1);
figure,imshow(carBW) % Display

carBW2 = imcomplement(carBW);
carBW3 = imfill(carBW2, 'holes');
% figure, imshow(carBW3)

carBW4 = bwareaopen(carBW3,5000);
% figure,imshow(carBW4)

[carBWLabel1,numOfDigits1] = bwlabel(carBW4,8);

for loop = 1:1:numOfDigits1
    total1(loop) = bwarea(find(carBWLabel1==loop));
end

labelPos = find(total1 == max(total1));

[r,c] = find(carBWLabel1==labelPos);
offset = -50;
rmin = min(r) - offset;
rmax = max(r) + offset;
cmin = min(c) - offset;
cmax = max(c) + offset;
carplateRGB = imcrop(carRGB,[cmin rmin (cmax-cmin) (rmax - rmin)]);
figure, imshow(carplateRGB)

%% Convert from RGB to Grayscale
carplateI = rgb2gray(carplateRGB);
```

```
% figure,imshow(carplateI) % Display
% figure,imhist(carplateI) % Display

%% Test threshold
% figure,imshow(carplateI > 125)

%% Determine global image threshold using Otsu's method
level = graythresh(carplateI)

%% Convert image to binary image, based on threshold
carplateBW = im2bw(carplateI,level);
figure,imshow(carplateBW) % Display

[labels1,numOfDigits1] = bwlabel(carplateBW,8);

%% Check Statistics
% for loop = 1:1:numOfDigits1
%     total2(loop) = bwarea(find(labels1==loop));
% end

%% Morphologically open binary image (remove small objects)
carplateBWFilter1 = imclearborder(carplateBW, 8);

carplateBWFilter2 = bwareaopen(carplateBWFilter1,5000);
figure,imshow(carplateBWFilter2)

[labels2,numOfDigits2] = bwlabel(carplateBWFilter2,8);

%%
for loop = 1:numOfDigits2
    [r,c] = find(labels2==loop);
    offset = 5;
    rmin = min(r) - offset;
    rmax = max(r) + offset;
    cmin = min(c) - offset;
    cmax = max(c) + offset;
    digitsBW{loop} = imcrop(carplateBWFilter2,[cmin rmin (cmax-cmin),...
        (rmax - rmin)]);
    figure, imshow(digitsBW{loop})
end
```

15.4 Data for Object Area (BWAREA)

No	Vehicle License Number	Raw Value			Remarks
1	SGX2572T	68241	68355	62302	OK
		68578	74191	47287	
		67763	44368		
2	SFZ5345P	44238	39085	44886	OK
		49702	47989	41159	
		47654	40249		
3	GU1408H	45092	40396	19425	REFLECTION
		38655	43987	51200	
		40068			
4	SGK6300D	57968	58189	54626	OK
		60964	56243	56526	
		56419	56326		
5	SGW845A	52219	53539	67879	
		68170	53649	63883	
		50781			
6	SGV6176M	52290	53285	45936	
		60157	25232	36879	
		57394	65240		
7	SFH5705D	46472	40995	48697	
		52544	32867	51193	
		51755	51258		
8	SDE8385M	47264	52741	54082	DENTED
		57443	50839	55627	
		48270	54383		
9	SFA1252G	45235	41713	41492	
		23125	46961	52503	
		48217	47281		
10	SGA9614G	57220	58005	50688	
		63966	63037	26276	
		50389	52684		
11	SFK2720M	36605	30576	36018	
		36866	25083	37619	
		40695	50117		
12	SFE9683Y	44973	40140	51944	MORE TO
		50971	52046	56945	WHITE BACKGD
		51246	30646		
13	SFS6465G	48140	42197	48394	
		55185	44953	54010	
		51631	45218		
14	SFT3769U	33983	30766	24676	
		39277	25776	40347	

		40006	33993		
15	SFZ2067L	47491	42192	47897	
		48917	50920	56048	
		35662	32367		
16	SFP4546K	48102	42123	46569	
		44786	52903	44817	
		56051	46937		
17	SFE6912G	35816	29711	39176	
		40283	38842	14568	
		34665	29740		
18	SFM4148S	23457	19327	29476	
		20319	9921	20033	
		27437	22633		
19	PA8992P	28923	25731	35790	
		35724	35624	31234	
		28410			
20	PA2266S	42987	41142	47989	
		47468	51088	50772	
		46024			
21	SGB1531J	20869	21977	27922	
		11048	25373	24557	
		10951	14683		
22	CB9348S	43603	57138	53875	
		42258	41467	53723	
		45910			
23	CB6013C	62316	82938	75245	
		79782	30384	63718	
		61116			
24	PA5173G	78869	76323	95370	
		41868	59641	87794	
		91077			
25	CB4876S	39584	52158	39642	
		50684	29176	47352	
		42802			
26	GY1312D	15681	10844	7602	
		16756	7525	16724	
		17942			
27	SGL379C	44806	45711	28867	
		50131	45584	29508	
		48938	35643		
28	SFT320A	66399	57483	45053	
		69908	66815	69486	
		58639			
29	SGJ6495E	39187	40752	26253	
		44578	36434	46758	
		43294	40767		

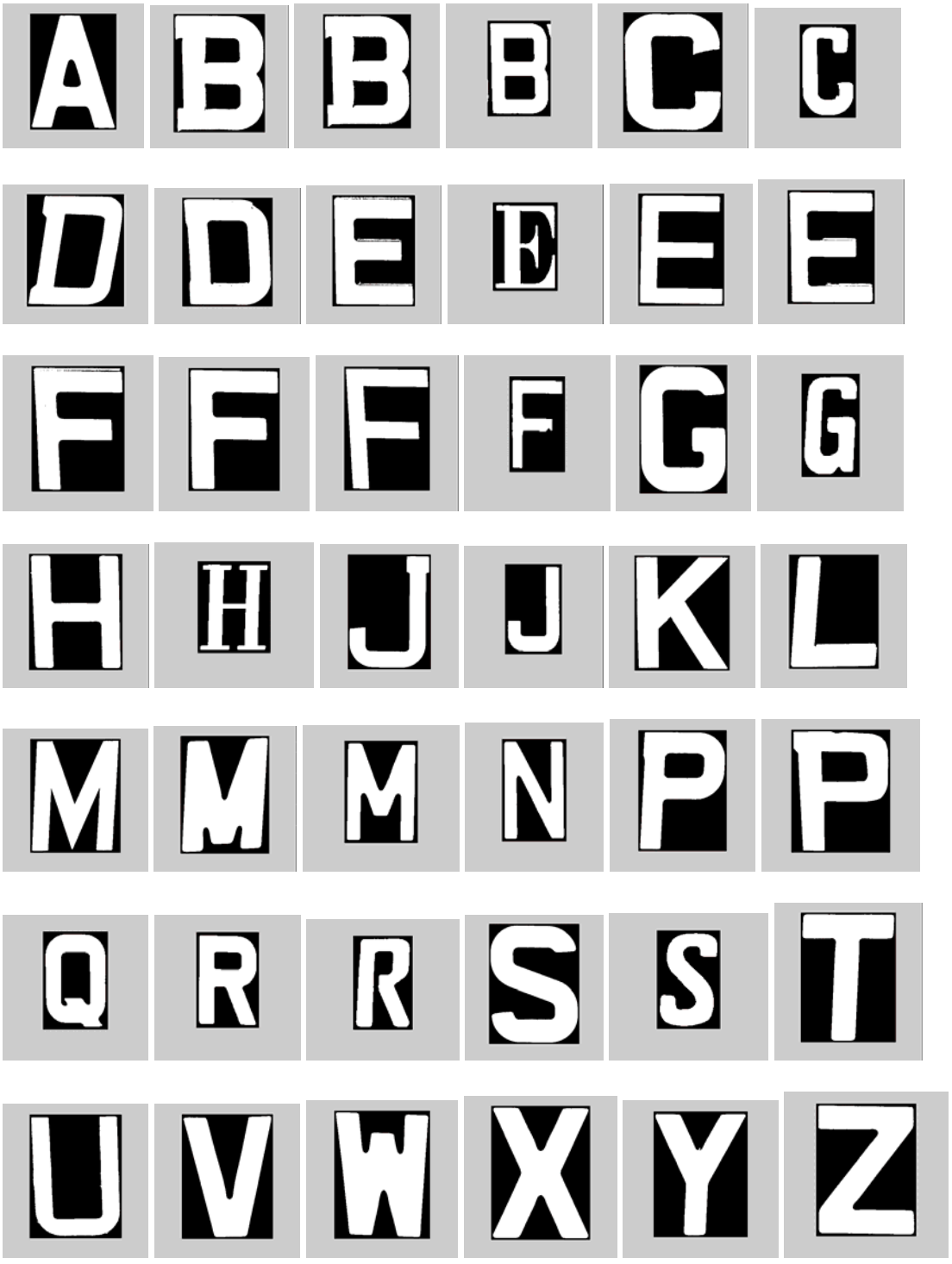
30	SGR2114P	12109 14287 16079 14846 6670 6356 11280 10003	
31	GY9163P	13928 9197 16755 7112 16987 14439 12624	
32	GX5949X	13214 11336 14663 15261 12162 15293 11322	
33	SFQ6077D	11373 10164 13184 13115 12016 8044 7978 12408	
34	SJA9142R	11189 7545 10103 12963 5076 10614 11343 11421	
35	SFG2549M	8763 7723 9549 10370 12064 9519 12099 12600	
36	AGF9922	15091 17320 13146 14201 14201 14131 14077	
37	SGY1269X	6447 6692 4684 3099 7538 8385 8006 5935	
38	SFG4298Z	9783 7853 9866 9135 9975 10988 11694 8618	
39	SDW187B	7605 8983 9833 3991 10002 5606 9259	
40	EY8713H	6951 5907 7748 5465 4129 6934 8166	
41	SGE6713C	19137 19108 21415 21591 13053 8907 19817 14978	
42	SFR2334P	9772 8588 11766 10361 11098 10978 9393 10190	
43	SBV9614E	8521 10511 6831 9631 9630 3819 8262 8240	
44	SFQ6876P	5317 4474 6068 6851 7469 4109 7152 5595	

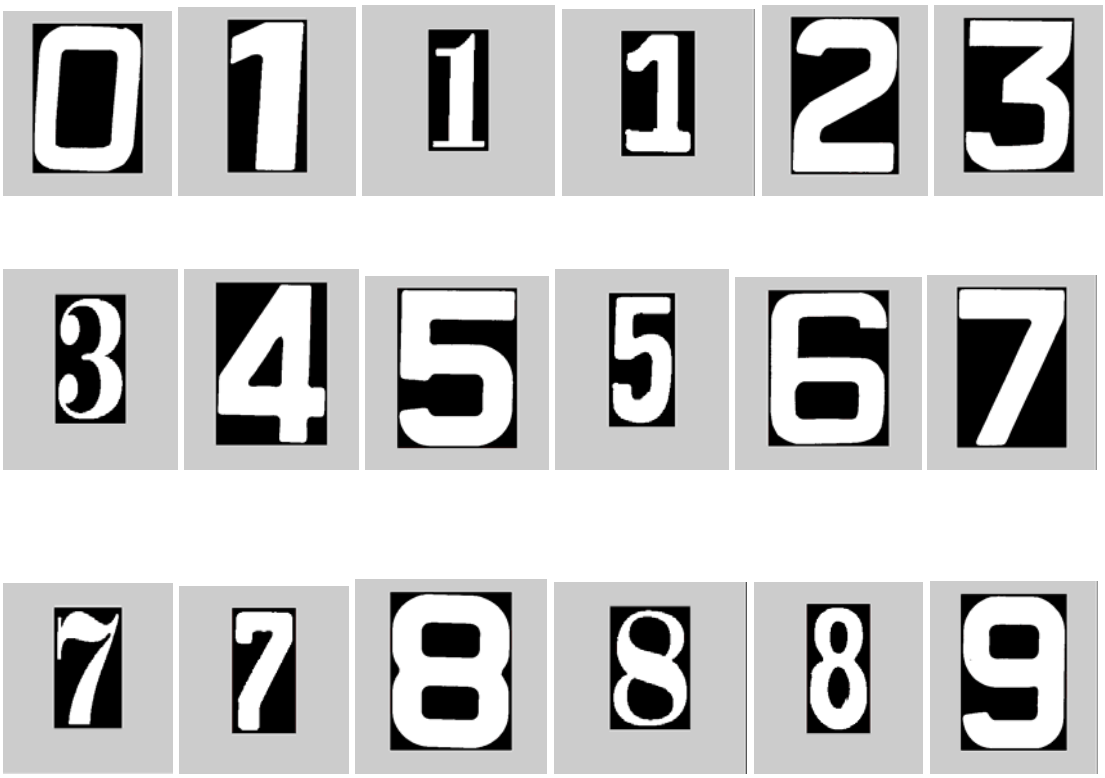
45	SGS8721S	12990 13484 13346 16520 8832 12890 5869 13200	
46	SGZ8252S	10280 10579 10475 12874 10880 11770 10799 10306	
47	SGZ2152L	10345 10452 10422 10492 4424 10989 9632 5598	
48	SFV277G	8532 7154 7131 9216 6092 6160 9589	
49	SGR5718C	8918 9853 9693 9010 7475 7705 9146 8039	
50	SJB5983B	8407 5839 10748 9448 9849 10149 8446 10176	
51	SGK9434G		DISTORTED
52	SFS2292P	7378 6148 7421 7328 7421 8759 7505 7070	
53	SJC6402A	8876 6255 8077 11867 8942 10921 10477 8224	
54	SFV2354D	8977 7571 7510 9601 9525 10565 8323 9883	
55	SFZ7946S	8048 7175 8321 6008 9722 7952 9528 8166	
56	SFN3362R	9740 8173 11853 10569 10575 11777 9826 10882	
57	SFK2440X	8070 6662 7951 8448 7634 7502 8729 6879	
58	CHANGE PIC ()		TOO DARK
59	SGA9270P		REFLECTION
60	SFK1314J		TOO DARK
61	SFC850B	8344 7082 7230 10275 9252 8907	

		9684	
62	CHANGE PIC (61)		
63	SJB9609G	7636 5363 10395 9702 9915 9361 9724 7984	
64	SFD2609P	12581 10584 13903 13698 15216 13770 14869 12027	
65	SFY9508R	6319 5511 4387 7615 7495 7282 8111 7164	
66	SGV3516K	12470 12805 11122 13861 14276 6311 14689 11713	
67	SCQ3138S	10431 9091 12152 11262 5214 11573 13172 11212	
68	SGZ2514B	14314 14657 14764 16174 18124 6835 13967 19076	
69	SGJ9747J	10003 10467 7007 11745 6674 9487 6745 6922	
70	SGC5065G	11393 11647 9865 12835 11958 12860 12338 10880	
71	SGQ8447U	4303 4437 5170 5565 4109 4109 3099 4202	
72	SGJ1131M	10333 10473 7055 5088 5108 11714 5181 14340	
73	SFF206X	12580 10633 10478 12551 13405 14569 10978	
74	SGN7768R	20737 21482 24129 13964 13937 23094 24731 22459	
75	SFH8219X	10579 8928 10597 13463 11189 4781 12211 8725	
76	SGA1804C	12695 13342 117162 6592 16293 14111 12070 10465	

77	SFJ3897K	9030 7730 5856 9553 11203 10127 5949 8831	
78	SFG4478X	10691 8719 11287 9954 9821 7072 13726 9455	
79	SFN1232X	7300 6021 8780 3366 7309 7685 7360 6672	
80	SDY2052H	8155 9262 5506 8517 8967 9517 8590 8506	
81	SHB3613G	13566 13938 17508 14579 16548 6841 14939 14774	
82	SBR4952H	9066 11283 10365 8238 10710 10231 9538 9261	
83	PH2548S	10452 11730 11692 13241 10556 14718 13097	
84	SDT3894P	12224 14147 8558 13494 15504 14333 11978 11863	
85	SFB7121G	11651 9934 14851 8270 5196 12482 5031 10710	
86	GX9610X	10349 8833 12488 12605 4523 11471 8943	
87	SGR1429M	13561 13639 15759 6155 12865 15151 16638 16540	
88	SGR7943E	12274 12096 13345 9072 14044 11154 12007 11569	

15.5 CHARACTER DESIGN OF ALPHANUMERIC DATABASE





Hidden layer 30 **, Goal 0. 1**

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	30	0.1	SGX2572T	SGX2572T	100%	
2	30	0.1	SFZ5345P	SFZ5345P	100%	
3	30	0.1	SGR7943E	SGP7943E	100%	
4	30	0.1	SGK6300D	SGK6300D	100%	
5	30	0.1	SGW845A	SGW845A	100%	
6	30	0.1	SFF206X	SFF20EX	85.71%	*
7	30	0.1	SFH5705D	SFH67050	75.0%	*
8	30	0.1	SGX2514B	SGE2514D	75.0%	*
9	30	0.1	SFA1252G	SFA1252G	100%	
10	30	0.1	SGA9614G	SGA9G14G	87.5%	*
11	30	0.1	SFK2720M	SFK0700M	75.0%	*
12	30	0.1	SFE9683Y	SFE9G83Y	87.5%	*
13	30	0.1	SFS6465G	SFS8485G	100%	
14	30	0.1	SFT3769U	SFT37G9U	87.5%	*
15	30	0.1	SGR1429M	SGP1429M	100%	

Hidden layer 8 **, Goal 0. 1**

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	8	0.1	SGX2572T	SGX2572T	100%	
2	8	0.1	SFZ5345P	SFZBA45P	75.0%	*
3	8	0.1	SGR7943E	6GR79T3E	75.0%	*
4	8	0.1	SGK6300D	6GK6300D	87.5%	*
5	8	0.1	SGW845A	SGW84XZ	71.43%	*
6	8	0.1	SFF206X	8FH5G64	28.57%	*
7	8	0.1	SFH5705D	6^{TH}59U5D	37.5%	*
8	8	0.1	SGX2514B	6G3ITBTD	12.5%	*
9	8	0.1	SFA1252G	SFA1D5J0	46.88%	*
10	8	0.1	SGA9614G	SGA96140	87.5%	*
11	8	0.1	SFK2720M	8FSD8DUM	25.0%	*
12	8	0.1	SFE9683Y	SFE9SSBY	46.88%	*

13	8	0.1	SFS6465G	SFSSAS50	50.0%	*
14	8	0.1	SFT3769U	SFTE7590	46.88%	*
15	8	0.1	SGR1429M	9GP1FJ9M	50.0%	*

Hidden layer 16 **, Goal 0. 1**

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	16	0.1	SGX2572T	SGX2572T	100%	
2	16	0.1	SFZ5345P	SFZE345P	87.5%	*
3	16	0.1	SGR7943E	8GR78XFE	50.0%	*
4	16	0.1	SGK6300D	SGK63LDD	75.0%	*
5	16	0.1	SGW845A	SSW8458	75.0%	*
6	16	0.1	SFF206X	SE6GD8X	28.57%	*
7	16	0.1	SFH5705D	EFH390E0	37.5%	*
8	16	0.1	SGX2514B	9G72E14R	50.0%	*
9	16	0.1	SFA1252G	SGW1252G	100%	
10	16	0.1	SGA9614G	SGW9814D	75.0%	*
11	16	0.1	SFK2720M	EF22320M	46.88%	*
12	16	0.1	SFE9683Y	SFE9G83Y	87.5%	*
13	16	0.1	SFS6465G	SFSG485D	75.0%	*
14	16	0.1	SFT3769U	SF7F789U	46.88%	*
15	16	0.1	SGR1429M	SGR1428M	87.5%	*

Hidden layer 150 **, Goal 0.** 01

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	150	0.01	SGX2572T	SGX2572T	100%	
2	150	0.01	SFZ5345P	SFZ5345P	100%	
3	150	0.01	SGR7943E	SGP7943E	100%	
4	150	0.01	SGK6300D	SGK6300D	100%	
5	150	0.01	SGW845A	SGW845A	100%	
6	150	0.01	SFF206X	SFF20FX	85.71%	*
7	150	0.01	SFH5705D	SFH57050	87.5%	*
8	150	0.01	SGX2514B	SGX2514D	87.5%	*
9	150	0.01	SFA1252G	SFA1252G	100%	
10	150	0.01	SGA9614G	SGA9614G	100%	
11	150	0.01	SFK2720M	SFK2720M	100%	
12	150	0.01	SFE9683Y	SFE9683Y	100%	
13	150	0.01	SFS6465G	SFS8485G	75.0%	*
14	150	0.01	SFT3769U	SFT3789U	87.5%	*
15	150	0.01	SGR1429M	SGP1429M	100%	
16	150	0.01	SFP4546K	SFP4546K	100%	
17	150	0.01	SFE6912G	SFE69120	87.5%	*
18	150	0.01	SGJ1131M	SGJ1131M	100%	
19	150	0.01	PA8992P	PA8992P	100%	
20	150	0.01	PA2266S	PA2288S	100%	
21	150	0.01	SGB1531J	SGB1531J	100%	
22	150	0.01	SFB7121G	SFB7121G	100%	
23	150	0.01	SDT3894P	SDT3894P	100%	
24	150	0.01	PA5173G	PA5179G	85.71%	*
25	150	0.01	CB4876S	CB4878S	85.71%	*
26	150	0.01	GY1312D	GY1312D	100%	
27	150	0.01	GX9610X	GX9810X	85.71%	*
28	150	0.01	SFT320A	SFT320A	100%	

29	150	0.01	SGR2114P	SGR2114P	100%	
30	150	0.01	GY9163P	GY9183P	85.71%	*
31	150	0.01	GX5949X	GX5949X	100%	
32	150	0.01	SGC5065G	SGC5QG5G	75.0%	*
33	150	0.01	SJA9142R	SJA9142R	100%	
34	150	0.01	SFG2549M	SFG2549M	100%	
35	150	0.01	AGF9922	A8F9922	85.71%	*
36	150	0.01	SGJ9747J	SGJ9747J	100%	
37	150	0.01	SFG4298Z	SFG4298Z	100%	
38	150	0.01	SDW187B	SDW1878	85.71%	*
39	150	0.01	EY8713H	EY8713H	100%	
40	150	0.01	SGE6713C	SGE8713C	87.5%	*
41	150	0.01	SFR2334H	SFR2334H	100%	
42	150	0.01	SBV9614E	FBV9614E	100%	
43	150	0.01	SBR4952H	SBH4952H	100%	
44	150	0.01	SGA1804C	SGA18Q4C	87.5%	*
45	150	0.01	SGZ8252S	SCZ8252S	87.5%	*
46	150	0.01	SHB3613G	SHB3613G	100%	

Hidden layer 40 **, Goal 0.** 01

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	40	0.01	SGX2572T	SGX2572T	100%	
2	40	0.01	SFZ5345P	SFZ5345P	100%	
3	40	0.01	SGR7943E	SGR7843E	87.5%	*
4	40	0.01	SGK6300D	SGK6300D	100%	
5	40	0.01	SGW845A	SGW845A	100%	
6	40	0.01	SFF206X	SFF206X	100%	
7	40	0.01	SFH5705D	SFHB705D	87.5%	*
8	40	0.01	SGX2514B	SGX2514P	87.5%	*
9	40	0.01	SFA1252G	SFA1252G	100%	
10	40	0.01	SGA9614G	SGA9614G	100%	
11	40	0.01	SFK2720M	SFK272UM	87.5%	*

12	40	0.01	SFE9683Y	SFE9E83Y	87.5%	*
13	40	0.01	SFS6465G	SFSG4G5G	75.0%	*
14	40	0.01	SFT3769U	SFT37690	87.5%	*
15	40	0.01	SGR1429M	SGR1428M	87.5%	*
16	40	0.01	SFP4546K	SFP4546K	100%	
17	40	0.01	SFE6912G	SFE69120	87.5%	*
18	40	0.01	SGJ1131M	SGJ1131H	87.5%	*
19	40	0.01	PA8992P	PA8992P	100%	
20	40	0.01	PA2266S	PA2288S	71.43%	*
21	40	0.01	SGB1531J	SGB1531J	100%	
22	40	0.01	SFB7121G	SFB71210	87.5%	*
23	40	0.01	SDT3894P	SDT3894P	100%	
24	40	0.01	PA5173G	PA5178G	85.71%	*
25	40	0.01	CB4876S	CB4878S	85.71%	*
26	40	0.01	GY1312D	UY1312U	71.43%	*
27	40	0.01	GX9610X	GX881QX	57.14%	*
28	40	0.01	SFT320A	SFT32QA	85.71%	*
29	40	0.01	SGR2114P	SGR2114P	100%	
30	40	0.01	GY9163P	GY91G3P	85.71%	*
31	40	0.01	GX5949X	GX5949X	100%	
32	40	0.01	SGC5065G	SGC5Q85G	75.0%	*
33	40	0.01	SJA9142R	SJAB142R	87.5%	*
34	40	0.01	SFG2549M	BFG2549M	87.5%	*
35	40	0.01	AGF9922	AQF9922	85.71%	*
36	40	0.01	SGJ9747J	SGJ9747J	100%	
37	40	0.01	SFG4298Z	8FG4288Z	75.0%	*
38	40	0.01	SDW187B	SDW187B	100%	
39	40	0.01	EY8713H	ET8713H	85.71%	*
40	40	0.01	SGE6713C	SGE8713C	85.71%	*
41	40	0.01	SFR2334H	SFR2334W	85.71%	*
42	40	0.01	SBV9614E	SBV9614E	100%	
43	40	0.01	SBR4952H	SBX48528	62.5%	*
44	40	0.01	SGA1804C	8GA18Q4C	75%	*
45	40	0.01	SGZ8252S	SCZ8752S	85.71%	*
46	40	0.01	SHB3613G	SHB3613G	100%	

Hidden layer 80 **, Goal 0.** 01

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	80	0.01	SGX2572T	SGX2572T	100%	
2	80	0.01	SFZ5345P	SFZ5345P	100%	
3	80	0.01	SGR7943E	SGR7843E	87.5%	*
4	80	0.01	SGK6300D	SGK6300D	100%	
5	80	0.01	SGW845A	SGW845A	100%	
6	80	0.01	SFF206X	SFF20BX	85.71%	*
7	80	0.01	SFH5705D	SFH5705D	100%	
8	80	0.01	SGX2514B	SGZ2514D	75.0%	*
9	80	0.01	SFA1252G	SFA1252G	100%	
10	80	0.01	SGA9614G	SGA9614G	100%	
11	80	0.01	SFK2720M	SFK2720M	100%	
12	80	0.01	SFE9683Y	SFE9883Y	87.5%	*
13	80	0.01	SFS6465G	SFS8465G	87.5%	*
14	80	0.01	SFT3769U	SFT3769U	100%	
15	80	0.01	SGR1429M	SGR1428M	87.5%	*
16	80	0.01	SFP4546K	SFP4546K	100%	
17	80	0.01	SFE6912G	SEE6B12G	75.0%	*
18	80	0.01	SGJ1131M	SGJ1131M	100%	
19	80	0.01	PA8992P	PA8882P	71.43%	*
20	80	0.01	PA2266S	PA2268S	85.71%	*
21	80	0.01	SGB1531J	SGB1531J	100%	
22	80	0.01	SFB7121G	SFB7121G	100%	
23	80	0.01	SDT3894P	SDT3894P	100%	
24	80	0.01	PA5173G	PA5179G	85.71%	*

25	80	0.01	CB4876S	CB4876S	100%	
26	80	0.01	GY1312D	GY1312D	100%	
27	80	0.01	GX9610X	GX8810X	71.43%	*
28	80	0.01	SFT320A	SFT320A	100%	
29	80	0.01	SGR2114P	SGR2114P	100%	
30	80	0.01	GY9163P	GY8183P	71.43%	*
31	80	0.01	GX5949X	GX5B49X	85.71%	*
32	80	0.01	SGC5065G	SGC5Q85G	75.0%	*
33	80	0.01	SJA9142R	SJAB142R	87.5%	*
34	80	0.01	SFG2549M	SFG254BM	87.5%	*
35	80	0.01	AGF9922	AQF9922	85.71%	*
36	80	0.01	SGJ9747J	SGJB747J	87.5%	*
37	80	0.01	SFG4298Z	SFG4288Z	87.5%	*
38	80	0.01	SDW187B	SDW187B	100%	
39	80	0.01	EY8713H	EY8713H	100%	
40	80	0.01	SGE6713C	SGE8713C	87.5%	*
41	80	0.01	SFR2334H	SFR2334H	100%	
42	80	0.01	SBV9614E	SBVB614E	87.5%	*
43	80	0.01	SBR4952H	SBR4852H	87.5%	*
44	80	0.01	SGA1804C	SGA18Q4C	87.5%	*
45	80	0.01	SGZ8252S	SGZ8252S	100%	
46	80	0.01	SHB3613G	SHB3613G	100%	

Hidden layer 150 **, Goal 0. 1**

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	150	0.1	SGX2572T	SGX2572T	100%	
2	150	0.1	SFZ5345P	SFZ5345P	100%	
3	150	0.1	SGR7943E	SGR7943E	100%	
4	150	0.1	SGK6300D	SGK6300D	100%	
5	150	0.1	SGW845A	SGW845A	100%	
6	150	0.1	SFF206X	SFF20FX	85.71%	*
7	150	0.1	SFH5705D	SFH57050	87.5%	*
8	150	0.1	SGX2514B	SGX2514D	87.5%	*

9	150	0.1	SFA1252G	SFA1252G	100%	
10	150	0.1	SGA9614G	SGA9814G	87.5%	*
11	150	0.1	SFK2720M	SFK2720M	100%	
12	150	0.1	SFE9683Y	SFE9883Y	87.5%	*
13	150	0.1	SFS6465G	SFS8485G	75.0%	*
14	150	0.1	SFT3769U	SFT3789U	87.5%	*
15	150	0.1	SGR1429M	SGR1429M	100%	
16	150	0.1	SFP4546K	SFP4546K	100%	
17	150	0.1	SFE6912G	SFE69120	87.5%	*
18	150	0.1	SGJ1131M	SGJ1131M	100%	
19	150	0.1	PA8992P	PA8992P	100%	
20	150	0.1	PA2266S	PA2288S	71.43%	*
21	150	0.1	SGB1531J	SGB1531J	100%	
22	150	0.1	SFB7121G	SFB7121G	100%	
23	150	0.1	SDT3894P	SDT3894P	100%	
24	150	0.1	PA5173G	PA5179G	85.71%	*
25	150	0.1	CB4876S	CB4878S	85.71%	*
26	150	0.1	GY1312D	GY1312D	100%	
27	150	0.1	GX9610X	GX981QX	71.43%	*
28	150	0.1	SFT320A	SFT320A	100%	
29	150	0.1	SGR2114P	SGR2114P	100%	
30	150	0.1	GY9163P	GY91F3P	85.71%	*
31	150	0.1	GX5949X	GX5949X	100%	
32	150	0.1	SGC5065G	SGC5QG5G	75.0%	*
33	150	0.1	SJA9142R	SJA9142R	100%	
34	150	0.1	SFG2549M	SFG2549M	100%	
35	150	0.1	AGF9922	A8F9922	85.71%	*
36	150	0.1	SGJ9747J	SGJ9747J	100%	
37	150	0.1	SFG4298Z	SFG4298Z	100%	
38	150	0.1	SDW187B	SDW1878	85.71%	*
39	150	0.1	EY8713H	EY8713H	100%	
40	150	0.1	SGE6713C	SGE8713C	87.5%	*
41	150	0.1	SFR2334H	SFR2334H	100%	
42	150	0.1	SBV9614E	SBV9614E	100%	
43	150	0.1	SBR4952H	SBR4852H	87.5%	*
44	150	0.1	SGA1804C	SGA18Q4C	87.5%	*
45	150	0.1	SGZ8252S	SCZ8252S	87.5%	*
46	150	0.1	SHB3613G	SHB3613G	100%	

Hidden layer 40 , Goal 0. 1

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	40	0.1	SGX2572T	SGX2572T	100%	
2	40	0.1	SFZ5345P	SFZ5345P	100%	
3	40	0.1	SGR7943E	SGR9843E	75.0%	*
4	40	0.1	SGK6300D	SGK6300D	100%	
5	40	0.1	SGW845A	SGW845A	100%	
6	40	0.1	SFF206X	SFF206X	100%	
7	40	0.1	SFH5705D	SFHB7050	75.0%	*
8	40	0.1	SGX2514B	SGX2514D	87.5%	*
9	40	0.1	SFA1252G	SFA1252G	100%	
10	40	0.1	SGA9614G	SGA9614G	100%	
11	40	0.1	SFK2720M	SFK272UM	87.5%	*
12	40	0.1	SFE9683Y	SFE9G83Y	87.5%	*
13	40	0.1	SFS6465G	SFSG4G5G	75.0%	*
14	40	0.1	SFT3769U	SFT37890	75.0%	*
15	40	0.1	SGR1429M	SGR142BM	87.5%	*
16	40	0.1	SFP4546K	SFP4546K	100%	
17	40	0.1	SFE6912G	SFE69120	87.5%	*
18	40	0.1	SGJ1131M	SGJ1131H	87.5%	*
19	40	0.1	PA8992P	PA8892P	8.71%	*
20	40	0.1	PA2266S	PA2288S	100%	
21	40	0.1	SGB1531J	SGB1531J	100%	
22	40	0.1	SFB7121G	SFB7121G	100%	
23	40	0.1	SDT3894P	SDT3894P	100%	
24	40	0.1	PA5173G	PA5178G	85.71%	*

25	40	0.1	CB4876S	CB4876S	100%	
26	40	0.1	GY1312D	UY1312U	71.43%	*
27	40	0.1	GX9610X	GX881QX	57.14%	*
28	40	0.1	SFT320A	SFT32QA	85.71%	*
29	40	0.1	SGR2114P	SGR2114P	100%	
30	40	0.1	GY9163P	GY91G3P	85.71%	*
31	40	0.1	GX5949X	GX5949X	100%	
32	40	0.1	SGC5065G	SGC5Q85G	75.0%	*
33	40	0.1	SJA9142R	SJAB142R	87.5%	*
34	40	0.1	SFG2549M	8FG2549M	87.5%	*
35	40	0.1	AGF9922	AQF9922	85.71%	*
36	40	0.1	SGJ9747J	SGJ9747J	100%	
37	40	0.1	SFG4298Z	8FG4288Z	75.0%	*
38	40	0.1	SDW187B	SDW187B	100%	
39	40	0.1	EY8713H	ET8713H	85.71%	*
40	40	0.1	SGE6713C	SGE6713C	100%	
41	40	0.1	SFR2334H	SFR2334W	87.5%	*
42	40	0.1	SBV9614E	SBVB614E	100%	
43	40	0.1	SBR4952H	SB848528	46.88%	*
44	40	0.1	SGA1804C	8GA18Q4C	75.0%	*
45	40	0.1	SGZ8252S	SCZ8752S	75.0%	*
46	40	0.1	SHB3613G	SHB3613G	100%	

Hidden layer 80 , Goal 0. 1

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	80	0.1	SGX2572T	SGX2572T	100%	
2	80	0.1	SFZ5345P	SFZ5345P	100%	
3	80	0.1	SGR7943E	SGR7843E	87.5%	*
4	80	0.1	SGK6300D	SGK6300D	100%	
5	80	0.1	SGW845A	SGW845A	100%	
6	80	0.1	SFF206X	SFF20BX	85.71%	*
7	80	0.1	SFH5705D	SFH5705D	100%	

8	80	0.1	SGX2514B	SGX2514D	87.5%	*
9	80	0.1	SFA1252G	SFA12520	87.5%	*
10	80	0.1	SGA9614G	SGA9614G	100%	
11	80	0.1	SFK2720M	SFK2720M	100%	
12	80	0.1	SFE9683Y	SFE9883Y	87.5%	*
13	80	0.1	SFS6465G	SFS8465G	87.5%	*
14	80	0.1	SFT3769U	SFT3789U	100%	
15	80	0.1	SGR1429M	SGR1428M	87.5%	*
16	80	0.1	SFP4546K	SFP4546K	100%	
17	80	0.1	SFE6912G	SEE6812G	75.0%	*
18	80	0.1	SGJ1131M	SGJ1131M	100%	
19	80	0.1	PA8992P	PA8882P	71.43%	*
20	80	0.1	PA2266S	PA2268S	85.71%	*
21	80	0.1	SGB1531J	SGB1531J	100%	
22	80	0.1	SFB7121G	SFB7121G	100%	
23	80	0.1	SDT3894P	SDT3894P	100%	
24	80	0.1	PA5173G	PA51790	71.43%	*
25	80	0.1	CB4876S	CB4876S	100%	
26	80	0.1	GY1312D	GY1312D	100%	
27	80	0.1	GX9610X	GX881GX	57.14%	*
28	80	0.1	SFT320A	SFT320A	100%	
29	80	0.1	SGR2114P	SGR2114P	100%	
30	80	0.1	GY9163P	GY8183P	71.43%	*
31	80	0.1	GX5949X	GX5848X	71.43%	*
32	80	0.1	SGC5065G	SGC5Q85G	75.0%	*
33	80	0.1	SJA9142R	SJAB142R	87.5%	*
34	80	0.1	SFG2549M	SFG2549M	100%	
35	80	0.1	AGF9922	AQF9922	85.71%	*
36	80	0.1	SGJ9747J	SGJB747J	87.5%	*
37	80	0.1	SFG4298Z	SFG4288Z	87.5%	*
38	80	0.1	SDW187B	SDW187B	100%	
39	80	0.1	EY8713H	EY8713H	100%	
40	80	0.1	SGE6713C	SGE8713C	87.5%	*
41	80	0.1	SFR2334H	SFR2334H	100%	
42	80	0.1	SBV9614E	SBVB614E	87.5%	*
43	80	0.1	SBR4952H	SBR4852H	87.5%	*
44	80	0.1	SGA1804C	SGA18Q4C	87.5%	*
45	80	0.1	SGZ8252S	SGZ8252S	100%	
46	80	0.1	SHB3613G	SHB3613G	100%	

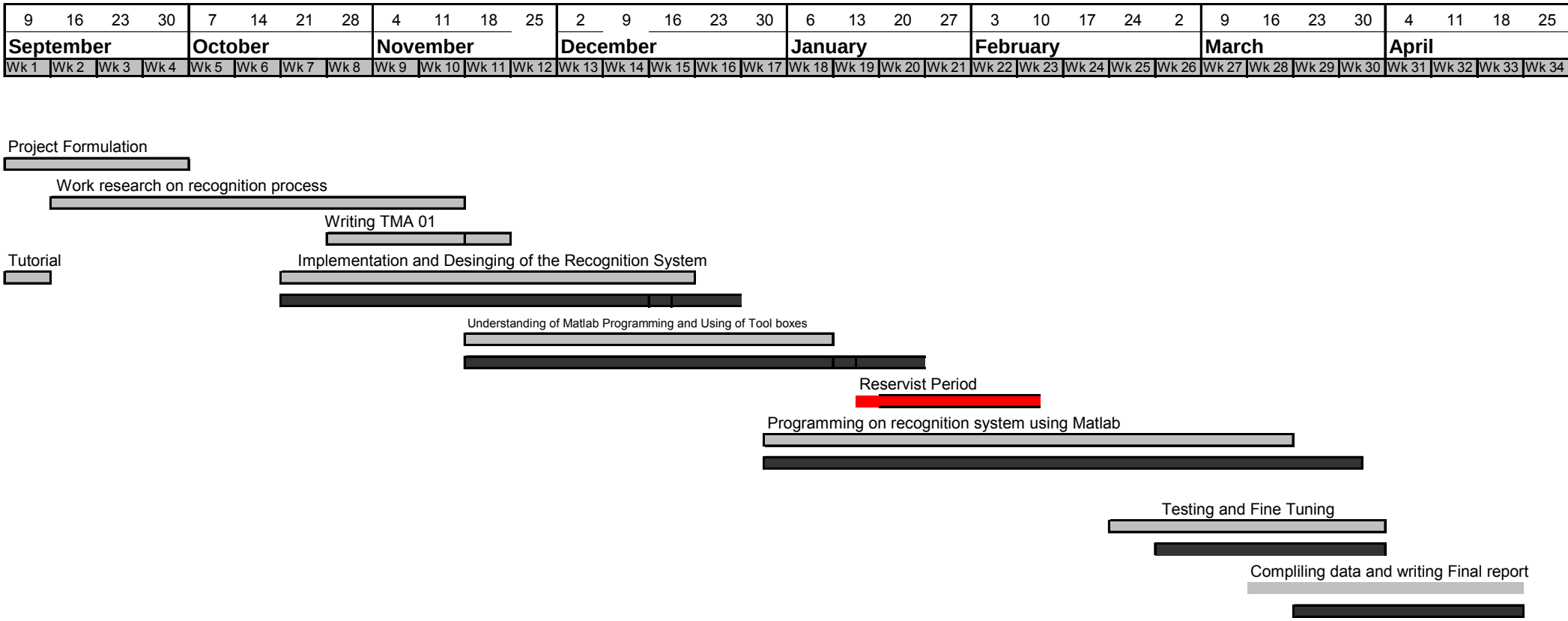
Hidden layer 64 , Goal 0.01

No	Hidden Layer	Goal	Vehicle License Number	Recognise Vehicle Number	Correctly Recognised	Remarks
1	64	0.01	SGX2572T	SGX2572T	100%	
2	64	0.01	SFZ5345P	SFZ5345P	100%	
3	64	0.01	SGR7943E	SGP7943F	75.0%	*
4	64	0.01	SGK6300D	SGK6300D	100%	
5	64	0.01	SGW845A	SGW845A	100%	
6	64	0.01	SFF206X	SFF206X	100%	
7	64	0.01	SFH5705D	SFH5705D	100%	
8	64	0.01	SGX2514B	SGX2514D	87.5%	*
9	64	0.01	SFA1252G	SFA1252G	100%	
10	64	0.01	SGA9614G	SGA9614G	100%	
11	64	0.01	SFK2720M	SFK2720M	100%	
12	64	0.01	SFE9683Y	SFE9883Y	87.5%	*
13	64	0.01	SFS6465G	SFS6465G	100%	
14	64	0.01	SFT3769U	SFT3769U	100%	
15	64	0.01	SGR1429M	SGP1429M	87.5%	*
16	64	0.01	SFP4546K	SFP4746K	87.5%	*
17	64	0.01	SFE6912G	SFE69120	87.5%	*
18	64	0.01	SGJ1131M	SGJ1131M	100%	
19	64	0.01	PA8992P	PA89927	85.71%	*
20	64	0.01	PA2266S	PA2288S	71.43%	*
21	64	0.01	SGB1531J	SGB1531J	100%	
22	64	0.01	SFB7121G	SFB7121G	100%	

23	64	0.01	SDT3894P	SDT3Q94P	87.5%	*
24	64	0.01	PA5173G	PA7178G	71.43%	*
25	64	0.01	CB4876S	CB4976S	85.71%	*
26	64	0.01	GY1312D	GY1312D	100%	
27	64	0.01	GX9610X	GX9610X	100%	
28	64	0.01	SFT320A	SFT320A	100%	
29	64	0.01	SGR2114P	SGR2114P	100%	
30	64	0.01	GY9163P	GY9163P	100%	
31	64	0.01	GX5949X	GX5949Y	85.71%	*
32	64	0.01	SGC5065G	SGC5Q65G	87.5%	*
33	64	0.01	SJA9142R	SJA9142P	87.5%	*
34	64	0.01	SFG2549M	SFG2549M	100%	
35	64	0.01	AGF9922	AQFVV1E	28.57%	*
36	64	0.01	SGJ9747J	SGJ9747J	100%	
37	64	0.01	SFG4298Z	SFG4299Z	87.5%	*
38	64	0.01	SDW187B	SDW1S7B	85.71%	*
39	64	0.01	EY8713H	EY8713H	100%	
40	64	0.01	SGE6713C	SGE6713C	100%	
41	64	0.01	SFR2334H	SFR2334P	87.5%	*
42	64	0.01	SBV9614E	FBV9614F	75.0%	*
43	64	0.01	SBR4952H	SBH4572F	50.0%	*
44	64	0.01	SGA1804C	SGA1804C	100%	
45	64	0.01	SGZ8252S	SGZ8252S	100%	
46	64	0.01	SGA1804C	SGA1804C	100%	

PROJECT SCHEDULE

(Project Schedule)



Black Blocks are the actual schedule.
Grey Blocks are the planned schedule.
Red Blocks are the reservist schedule