Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF AUTOMATIC NUMBER PLATE RECOGNITION SYSTEM USING NEURAL NETWORK

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Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Computer Engineering Technology (Computer Systems) with Honours

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2022

DECLARATION

I declare that this project report entitled "Development of Automatic Number Plate Recognition System using Neural Network" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

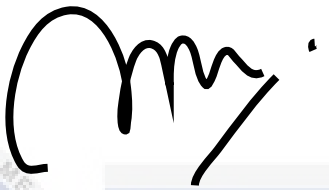
Signature : 

Student Name : Nur Zahirah Binti Alias

Date : 3 February 2023

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Computer Engineering Technology (Computer Systems) with Honours.

Signature : 

Supervisor Name : Ts. Dr. Rostam Affendi Bin Hamzah

Date : 3 February 2023

DEDICATION

To my beloved mother, Zainah Binti Muda, and father, Alias Bin Wahab,

and

To my dearest family and friends.

ABSTRACT

Automatic Number Plate Recognition (ANPR) system will read the image of a vehicles as input image then extracting the number plate as text. The main purpose of this system is to design and develop an efficient and systematic automatic vehicle identification system, which will use vehicle registration number plate as the parameter. The system will read the vehicle registration number plates as input and then it will automatically recognize the number plate's character as an output. This system is widely implemented in various sectors in the world, for example, in car parking management, traffic management, tolling and also Intelligent Transport System (ITS). Other than that, The Automatic Number Plate Recognition system is also being implemented as a security measure at the entrance of highly restricted areas, such as military zones or the top government offices. The developed Automatic Number Plate Recognition system identifies the incoming vehicle and then captures the vehicle's image. Image segmentation will be used to extract the vehicle number plate region from the captured image meanwhile for the character recognition, Optical Character Recognition (OCR) technique will be utilized. Next, the resulting data from the previous step will be compared with the entries in a database to determine the precise information. This system will be developed and simulated in the Matlab software and real-world images at the test subject. Based on the experiment, the developed system is able to identify and recognize the vehicle registration number plate successfully.

ABSTRAK

Sistem Pengecaman Nombor Plat Automatik (ANPR) adalah sistem yang akan membaca input image kenderaan dan mengeluarkan nombor plat kenderaan sebagai output. Objektif utama sistem ini adalah untuk mereka bentuk dan membangunkan sistem pengecaman kenderaan automatik yang cekap dan sistematik, yang akan menggunakan nombor plat pendaftaran kenderaan sebagai parameter. Sistem akan membaca nombor plat pendaftaran kenderaan sebagai input dan kemudian secara automatik akan mengecam nombor plat sebagai output. Sistem ini banyak dilaksanakan dalam pelbagai sektor di dunia contohnya dalam pengurusan tempat letak kereta, pengurusan trafik, tol dan juga Intelligent Transport System (ITS). Selain itu, Sistem Pengecaman Plat Nombor Automatik juga sedang dilaksanakan sebagai langkah keselamatan di pintu masuk kawasan larangan tinggi, seperti zon tentera atau pejabat tertinggi kerajaan. Sistem Pengecaman Plat Nombor Automatik yang dibangunkan mengenal pasti kenderaan masuk dan kemudian menangkap imej kenderaan. Pembahagian imej akan digunakan untuk mengekstrak kawasan nombor plat kenderaan daripada imej yang ditangkap manakala untuk pengecaman aksara, teknik Pengecaman Aksara Optik (OCR) akan digunakan. Seterusnya, data yang terhasil daripada langkah sebelumnya akan dibandingkan dengan entri dalam pangkalan data untuk menentukan maklumat yang tepat. Sistem ini akan dibangunkan dan disimulasikan dalam perisian Matlab dan imej dunia sebenar pada subjek ujian. Berdasarkan ujikaji, sistem yang dibangunkan dapat mengenal pasti dan mengecam nombor plat nombor pendaftaran kenderaan dengan jayanya.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligent
ALPR	-	Automatic License Plate Recognition
ANN	-	Artificial Neural Network
ANPR	-	Automatic Number Plate Recognition
B/W	-	Black/White
BRTA	-	Bangladesh Road Transport Authority
CCA	-	Canonical Correlation Analysis
CCN	-	Convolutional Neural Network
CS	-	Character Segmentation
DIP	-	Digital Image Processing
GUI	-	Graphical User Interface
HD	-	High Definition
ID	-	Identification
ITS	-	Intelligent Traffic System
LSTM	-	Long Short-Term Memory
NPL	-	Number Plate Localization
NPR	-	Number Plate Recognition
OCR	-	Optical Character Recognition
PSDB	-	Police Scientific Development Branch
RFID	-	Radio-Frequency Identification
RGB	-	Red Green Blue
ROI	-	Region of Interest
SD	-	Standard Definition
SoC	-	System on Chip
SUN	-	Scene Understanding
SVM	-	Support Vector Machine
VNP	-	Vehicle Number Plate
YOLO	-	You Only Look Once

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CHAPTER 1

INTRODUCTION

1.1 Background

Number plates have been used as a means of identification throughout the countries in the world. However, the upsurge of the number of automotive vehicles nowadays provides a huge challenge in the identification of the number plate. Considering this current situation, the manual tracking of the traffic on the roads will eventually become a lost cause since it is a total waste of the manpower and also time. Not only that, operating manually will also demonstrate massive difficulties and tons of errors. The existing system for reading the vehicle registration number plate uses machine learning algorithms. This system, however, will not be working efficiently in real time because of the complexity in the system for processing in the real time background. This essentially caused an immediate need to design an automatic number plate recognition system which can provide assistance in vehicle identification and recognition.

1.2 Problem Statement

Automatic Number Plate Recognition system (ANPR) is developed mainly to provide assistance to humans in automatically detecting and reading the vehicle registration number plates without any human intervention. Previously, a person was required to manually detect and record the vehicle registration number plate. This system is flawed as it is not only inefficient since humans are more prone to make mistakes, but also increases the

need for human labour. To overcome this problem, this system is being developed to completely replace human intervention in detecting the vehicle registration number plate and also recognize the number plate and identify it.

1.3 Project Objective

The primary goal of this project is to propose an ANPR system that can perform all of its functions efficiently. Specifically, the objectives are as below:

a) To design a system which is capable of extracting the number plate of the vehicle from the input image.

b) To develop a system that is capable of locating and reading the vehicle registration number plate.

c) To verify the performance of the proposed system by using several types of fonts and numbers.

1.4 Scope of Project

The purpose of this project is to develop and design an Automatic Number Plate Recognition system by using artificial neural networks. This system, which functions to identify vehicle registration number plates, will be implemented in the MATLAB software by using the Image Processing Toolbox and Computer Vision Toolbox. As a result, the scope for this project are as follows:

a) To develop a system that are capable of identifying vehicle registration number plates.

b) Data can be extracted from the input image by using Image Processing Toolbox.

c) The image of the vehicle registration number plate can be identified by using the neural network algorithm.

d) The final output will be produced in the text form.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Automatic Number Plate Recognition system is a system that essentially allows the computer systems to read the vehicle registration's number from the digital images automatically by using Optical Character Recognition (OCR). The invention of the ANPR system started in 1976 in the United Kingdom at the Police Scientific Development Branch (PSDB) or now known as Home Office Scientific Development Branch and the early systems were developed for use in 1979.

Number plate identification or recognition is a type of Intelligent Traffic System (ITS) Technology which will not only identify and count vehicles, but also distinguish each vehicle as unique. Number plate identification technology is very useful in some applications like electronic toll collection and also the red-light violation enforcement, as the system can record the vehicle registration number plate alphanumeric, so that the vehicle owner can be charged the appropriate toll or fine.

Another number plate identification technology is in commercial vehicle operations or in secure-access control. When a vehicle is entering an area, the number plate identification technology will check the vehicle registration number plate and compare it to the established database to determine whether the vehicle can be allowed to enter the area or not. Another use of the number plate identification system is that it can be used in traffic control management. The system will identify any vehicles that commit traffic violations,

such as driving in the emergency lanes, driving under influence, parking illegally and also exceeding speed restrictions.

The number plate identification is a novel digital image processing-based technique for the automatic vehicle and traffic monitoring. In this project, there are two main components in the implementation of the number plate identification system, which are the digital image processing and also the neural network.

This system will employ advanced and novel digital image processing techniques such as pattern recognition to recognize the vehicle registration characters and also artificial neural network to extract the data.

2.2 MATLAB

Programming, visualization, and calculation are all integrated into the user-friendly environment of MATLAB, which may be used to solve mathematical problems in standard notation. It was created by MathWorks in 1984 and has expanded over the years with the participation of various users. Additionally, it may be used to create user interfaces for a variety of programs written in a variety of languages and to communicate with other programs written in a variety of other languages.

Features of MATLAB software

- High-level programming language that can be used for numerical calculation, visualization, and the development of application.

- Has interactive settings that encourage iterative exploration, design, and also problem solving.
- Provide a large number of mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration, and solving ordinary differential equations.
- Has development tools which can be used to enhance code quality and maintainability and maximize performance.
- Tools for developing programs which have a customized graphical user interface.[1]

This ANPR system, which functions is to identify vehicle registration number plate, will be implemented in the MATLAB software by using Image Processing Toolbox and also the Computer Vision Toolbox.

2.3 Digital Image Processing

The digital image processing is the technique of using a digital computer to process digital image through an algorithm. Image Processing Toolbox is a comprehensive collection of standard algorithms, functions, and also applications that are useful for image processing, image analysis, image visualization and also algorithm development. By using the Image Processing Toolbox, the user can perform several tasks, for example, image analysis, image enhancement, noise reduction and also geometric modifications. [1]

Key Features of Digital Image Processing

- Can be used for image analysis, including image segmentation, image morphology, and image measurement.

- Can be used for image enhancement, image filtering and also deblurring.

2.3.1 Digital Image Reading

The imread function will be used to read images from any supported graphics file, in any of supported bit depth.

2.3.2 Image Binarization

The process of converting a grayscale image to a black-and-white image is known as image binarization. In this process the information, which resides in the image, will be reduced from 256 shades of grey to 2: black and white, and essentially produce the final output as a binary image. This technique is commonly referred to as image thresholding, despite the fact that the result of the thresholding technique is images with more than two levels of grey. It is a type of segmentation that will essentially break down an image into individual objects. Image binarization technique will usually be performed when an object needs to be extracted from an image.[1]

2.3.3 Morphological Operation

Morphological operations contain a comprehensive set of image processing techniques that are able to manipulate images depending on their shapes. The morphological techniques utilize structural elements to create an output image that has the same size as the input image. In the morphological process, the value of each pixel in the output image will be determined by comparing the corresponding pixel in the input image with its neighbours.

2.3.3.1 Erosion

In mathematical morphology, erosion is one of the two basic operators. The erosion method is most typically employed on binary images, however certain versions may also be implemented on grayscale images. On a binary image, the major consequence of erosion is that it erodes the borders of the foreground pixel areas. This operation will result in the size of the foreground pixel regions will shrink, while the spaces between them will expand.

Two pieces of data will be delivered to the erosion operator as input for the erosion process. One piece of data will be the input picture, which will be eroded, while the other set of data will be the structuring element, which is usually a limited number of coordinate points. The role of the structuring element is to determine the exact erosion impact on the input picture.

Properties of Erosion

- It can split apart joint objects.
- It can strip away extrusions.

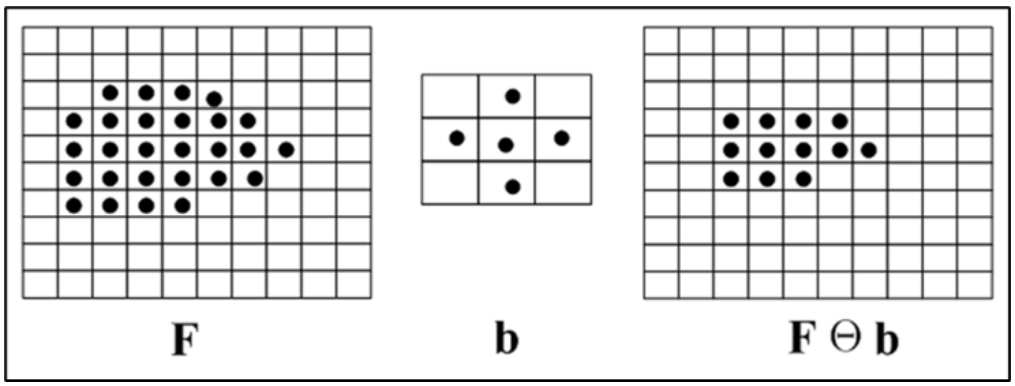


Figure 2.1Erosion technique on an input image by using structuring element[2]

2.3.3.2 Dilation

Dilation is another fundamental operator in mathematical morphology aside from erosion. The dilation technique is generally utilized on binary images, but there are also some variants of dilation that can operate on the grayscale images. The basic impact of the dilation on a binary image is that it will gradually extend the borders of the foreground pixels. As a result, the foreground pixel region will expand in size meanwhile the gaps within the region will shrink.

Properties of Dilation

- It can repair breaks.
- It can repair extrusions.

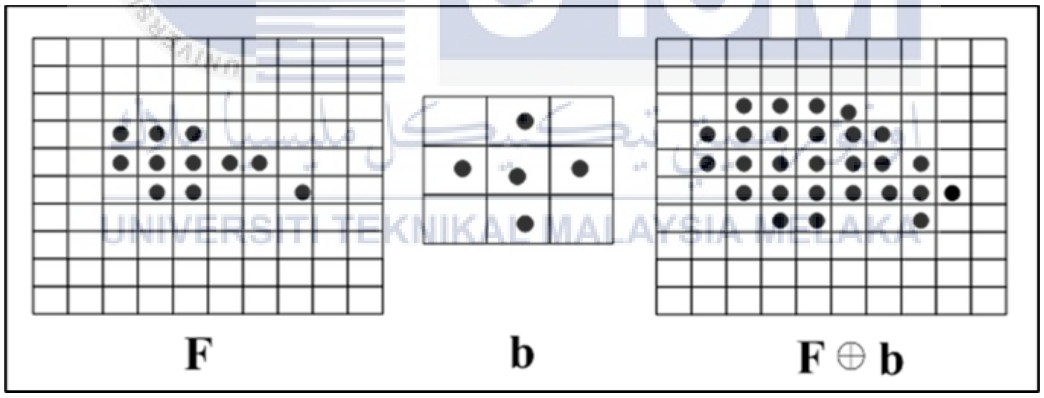


Figure 2.2Dilation technique on an input image by using structuring element.[2]

2.4 Machine Learning

Machine learning is one of the branches of artificial intelligence (AI) and computer science that implements data and algorithms to simulate how people learn and improve its accuracy over time. The process of obtaining, interpreting, and modelling data is known as

machine learning. To put it another way, machine learning is the process of teaching a machine to learn.

The first step of machine learning is data collection. The data is needed to train the machine and will be gathered from the available sources. Then, the learning needed to be cross validated to see whether the end results are close to the requirement or not. If the results are close to the requirements, the machine is learning successfully; otherwise, the machine needs to be trained again.

Three primary categories of machine learning :-

i) Supervised machine learning

ii) Unsupervised machine learning

iii) Semi-supervised machine learning

2.5 Supervised Machine Learning

The use of labelled datasets to train algorithms that consistently classify data or properly predict outcomes is referred to as supervised learning, also known as supervised machine learning[3]. The weights will be changed as additional data is added to the model until it matches exactly. During the cross-validation process, this condition will arise to ensure that the model is neither overfitting nor underfitting. The supervised machine learning approach can tackle many real-world issues at scale, such as spam categorization into various folders from the email inbox.

Supervised Learning can be divided into two broad categories :

I. Classification

- For responses with only a few predefined values, for example 'true' or 'false'. The classification algorithm can only be applied to the nominal values.

II. Regression

- For responses that are real numbers as the values, such as kilometers per hour for a particular vehicle's speed.

Supervised Machine Learning Techniques :-

- Neural Network
- Naïve Bayes
- Linear regression
- Logistic regression
- Random forest
- Support Vector Machine (SVM)

2.5.1 Artificial Neural Network

Neural networks are one of the subsets of machine learning and serve as the basis for deep learning algorithms. They are also known as the artificial neural networks (ANNs). The human brain served as an inspiration for both the name and construction of the neural network, which also aimed to emulate the method in which organic neurons interact with one another.

There is something called node layer that may be found in artificial neural networks. This node layer will include an input layer, as well as one or more hidden levels, and an

output layer. Every node, also known as artificial neuron, is connected to all of the other nodes in the network, in addition to having its own weight and threshold. If there is a node in the network whose output is greater than the threshold value, that specific node will be activated and will start transferring data to the network's next layer as soon as possible.

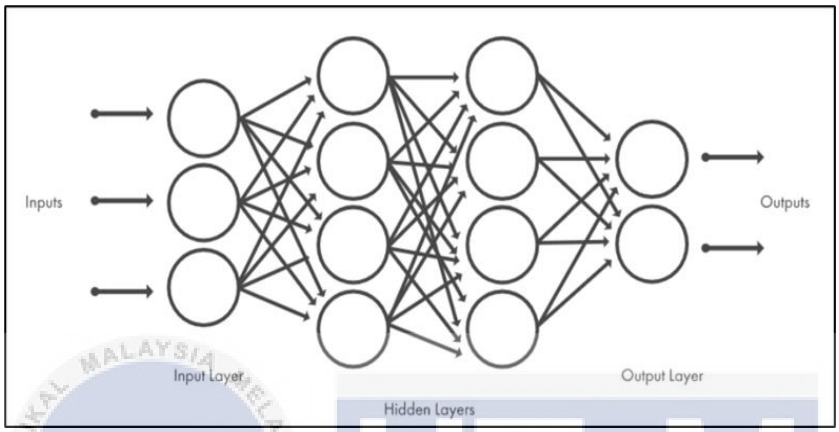


Figure 2.3 Typical Neural Network Architecture [4]

Three types of layers in artificial neural networks :

I. Input layer

- Artificial input neurons make up the input layer of artificial neural networks. They send the first data into the system so that the next layers of artificial neurons can figure out what to do with it. The first step in making an artificial neural network is the input layer.

II. Hidden layer

- A hidden layer is between the input and output layers of an artificial neural network. Activation functions are used in the hidden layer to create and output from a collection of weighted inputs. It is a standard part of every

neural network, and the engineers may use it to mimic the kinds of neural activity seen in the human brain.

III. Output layer

- The output layer is the last layer of the neuron that will generate the output. Because there are the last nodes on the network, the output layer neurons may be generated or monitored differently compared to the other artificial neurons in the neural network.

2.5.2 Neural Network Design Steps

The standard steps for designing neural networks are needed to address the problem in four application areas which are the function fitting, pattern recognition, clustering, and also the time-series analysis.

Seven major processes in designing neural networks :-

I. Data collection

II. Construct a network

III. Network configuration

IV. Initialization of weights and biases

V. Network training

VI. Network validation

VII. Use the network

2.5.3 Topologies of Neural Network

The topology of neural networks is a term that means the way the neurons are connected, and it is the key aspect in network functioning and learning.

Example of Artificial Neural Network Topologies

- Feed forward neural network
- Convolutional neural network
- Recursive neural network
- Recurrent neural network
- Stack denoising auto-encoders
- Deep Boltzmann machine
- Self-Organizing Maps
- Deep Belief networks

2.5.4 Logistic Regression

Logistic regression is a simple form of neural network which is able to categorize data. It can be utilized when the target variable has two categories of value, such as true or fault, spam or not spam. Logistic regression works by taking an input and running it through a function which is known as the sigmoid function[5]. The sigmoid function will then provide a probability between 0 and 1. This sigmoid function is in charge of categorizing the input.

$$S(x) = \frac{1}{1 + e^{-x}}$$

2.5.5 Feedforward Network

The feedforward neural networks, also known as Deep feedforward networks or Multi-layer Perceptron are the quintessential deep learning model. It is a type of artificial neural network in which they do not have cycles or loops in their connections [6]. The feedforward is the basic type of neural network because the information in it will be processed in one direction only. The data may transit through multiple hidden nodes, but it will always flow forward and never backward in the networks. First, the data will travel through the input nodes, then through the hidden nodes if there are any in the circuit, and lastly through the output nodes. When the data that needs to be learnt is not sequential or time dependent, the feedforward neural networks are most typically utilized for supervised learning.

2.5.6 Back Propagation

The most integral role of training a neural network is call backpropagation. The weights of a neural network may be fine-tuned using a process known as backpropagation. This approach adjusts the weights of the network based on the error rate of the most recent epoch. It is possible to lower the error rates and enhance the model's generalizations via the process of fine-tuning the weights, both of which will ultimately lead to an improvement in the dependability. Calculating the gradient of a loss function with respect to the weights of a network is made easier with the help of the backpropagation method.

The backpropagation algorithm can compute the gradient of the loss function for a single weight by using chain rule. It is very efficient to compute one layer at a time compared to native direct computation.

2.6 Optical Character Recognition

OCR, also known as optical character recognition, is defined as the process of electronically or mechanically converting any images of typed, handwritten, or printed text into machine-encoded text. This process can be done from a scanned document, a photograph of a document, or a scene-photo; for example, is the text on sign road and also the text in banner.

Optical character recognition is a popular approach of digitizing printed texts so that they can be electronically edited, searched, stored more compactly, displayed on-line, and used in machine processes such as cognitive computing, and machine translation. It is widely utilized as a form of data entry from printed paper data records, including passport documents, invoices, bank statements, computerized receipts, business cards, mail, printouts of static-data, and any other suitable documentation.

The early versions of optical character recognition required the users to train the program using the images of each character, and only supported one font at a time. The advanced systems of optical character recognition now are able to produce a high degree of recognition accuracy for the majority of common fonts like Arial, Times New Roman and Tahoma, and it also support a number of different digital image file formats, such as PNG, JPG, JPEG, GIF and TIFF, as input.

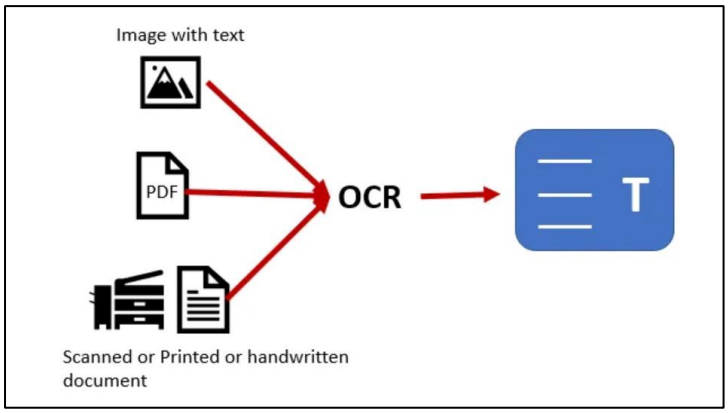


Figure 2.4 OCR diagram [7]

2.6.1 Techniques of Optical Character Recognition

2.6.1.1 Pre-processing

All the input images will go through the pre-processing phases by the OCR software. This step is very important to increase the likelihood of successful recognition.

Several pre-processing techniques:-

- De-skew – If the alignment of input image is off, it will reduce the chance of successful output. So, it is necessary to tilt it a few degrees in either direction to make the text lines perfectly horizontal or vertical.
- Despeckle – Eliminate the positive and negative spots on the images and also smooth the edges.
- Line removal – Eliminate the non-glyph boxes and lines
- Layout analysis – Identify the columns, and paragraphs as a distinct block especially in to detect text in multi-column layouts and tables.

2.6.1.2 Text Recognition

Matrix matching, also known as pattern matching, pattern recognition, or image correlation, is the process of comparing an image or picture to a collection of stored glyphs, pixel by pixel. For this to work properly, the input glyph must be correctly separated from the rest of the image, and the stored glyph must have a similar typeface that is comparable and has same scale. This method is most effective when used with typewritten materials and not performing well when using unfamiliar fonts. The early physical photocell-based OCR implemented this type of method rather directly.

2.6.1.3 Post-processing

The accuracy of optical character recognition can be increased and improved if the output is constrained by a lexicon —a list of words that are allowed to appear in a document. For instance, this might be the entire English language, or a more technical vocabulary for a particular field, for example, engineering, medicine and bioengineering. This technique, however, can be challenging if the text in the document contains words that are not in the lexicon, like proper nouns. The Tesseract influences the character segmentation process by using its dictionary to increase the accuracy of the output. The output stream may be a plain text stream or character file, but the more complex or sophisticated OCR systems can preserve the original layout of the page and generate, for example, an annotated PDF including both the original image of the page and a textual representation that is searchable.

2.6.2 Applications of Optical Character Recognition

The OCR technology is widely uses in variety of applications, including the following:

- Automatic number plate recognition

- Assistive technology for blind and visually impaired users
- Data entry for business documents, e.g. check, bank statement and invoice
- In airports, for passport recognition and information extraction
- Making scanned documents searchable by converting them to searchable PDFs

2.7 Related Previous Work

To gain better understanding about the project, I conducted some research on the prior projects that related to the Automatic Number Plate Recognition system. The information that I received from this research will assist in the development of the project.

In [8], [9], the author of this project designed a deep learning model which aims to recognize the number plate by using the Turkish dataset. They used the Tensorflow framework with the Keras deep learning library. A total of 34,580 images, which have the resolution of 640x360 pixels, were collected as the test subject for the project. The smearing algorithm will be applied to the images using a MATLAB program for plate detection. The images will go through data tagging and then divided into 3 groups which are 5% for validation, 20% for testing and lastly, 75% for training. Considering that the images used as the test subject were taken from the real time background, they needed to carry out several image processing techniques to essentially enhance it like Adaptive Gaussian thresholding, median blur smoothening and morphological transformations. All these steps are very crucial for the next steps in which all the images will be used to train the CNN model. In this step, the image features will be first extracted from CNN before being applied to the LSTM network and then followed by the decryption algorithm. From this method, they are able to

achieve an overall accuracy as high as 96.36% for the plates, 99.43% for numbers, 99.05% for letters, and 99.31% for all the characters.

In the paper[10], the authors conducted a survey on various methodologies that can be used to implement Automatic Number Plate Recognition (ANPR). The basic steps for the Automatic Number Plate Recognition are including vehicle image capture, number plate detection, Character segmentation and Character recognition. For each of these steps, several crucial factors need to be taken into consideration as it will affect the accuracy of the system. In order to successfully identify license plates, it was necessary to take into account a variety of parameters, including plate placement, plate backdrop, plate size, and screw. According to the findings of the study, Canny's edge detection has the potential to attain the highest level of accuracy for plate detection. Image binarization, Connected Component Analysis (CCA), vertical and horizontal projection are some of the techniques that may be used in character segmentation. These techniques can be used in order to provide better results. Character recognition may then be accomplished via the use of methods such as template matching, Optical Character Recognition (OCR), or Artificial Neural Networks (ANN). When it comes to character recognition, tesseract OCR is capable of reaching an accuracy level of up to 98.7 percent at its very best.

In paper [11], deep learning techniques were used by the authors during the course of this study in order to construct a plate recognition system. When developing an OCR system, a customized dataset is used. This dataset was produced in an artificial manner by gathering photographs from an online database and then adding additional background and noise to the images. They utilized the SUN database and the Stanford database for the

backdrop, and they employed an object detection framework for the number plate identification technique known as YOLO, which stands for "You Only Look Once." In order to do character recognition, a Convolutional Neural Network, or CNN, is used. In order to reach the desired level of accuracy, the CNN output layer will be built with 7.62 neurons for each of the 7 characters, and it will use 10-fold-cross validation at the output. The total accuracy that can be reached with CNN character recognition is around 96.8%, whereas the accuracy that can be achieved with CNN plate detection is 98.5%. This OCR-based system has a total efficiency that is 94% effective across the board.

In the paper[12], the authors worked on this project to create a number plate recognition system by using the Convolutional Neural Network. The images used in this project will be taken from a camera and went through several processes which are converted to the grey scale from the RGB image, noise removal and also binarization. The images needed to be preprocessed to ensure the quality of the image. The Connected Component method will be used to extract the license plate depending on several properties such as area, bounding box, major axis length and minor axis length. Horizontal and vertical scanning will be used to segment the character from the extracted license plate and finally in the last step, all the characters will be recognized using Convolutional Neural Network (CNN). The dataset that was used to train the CNN consists of 1000 images for each of the 36 characters. From the 36,000 images, 6000 samples are used for testing data meanwhile 30,000 samples used as the training data.

2.8 Comparison Table of Previous Related Works

Table 2-1 Comparison table of previous related works

No.	Authors	Title	Year	Functional	Remarks
1	Pallavi Khare; Rupesh Dudhe; Amolsing Chungade; Ajit Naykinde.	Advanced License Number Plate Recognition System[13]	2018	The plate number will be recognized and transferred using the encryption and decryption technique through network channel. The image is integrated with the first recognized characters, and the data is encrypted with the sender's private key.	The ANPR System is developed by using Optical Character Recognition (OCR). **Disadvantages of ANPR system using OCR** • Misidentification • Hazy images • Flaws in angular detection
2	Ali Farhat; Omar Hommos; Ali Al-Zawqari; Abdulhadi Al-Qahtani; Faycal Bensaali; Abbes	Optical Character Recognition on Heterogeneous SoC for HD Automatic Number Plate	2018	**Main stages of typical ANPR system:-** 1) Number Plate Localization (NPL) 2) Character Segmentation (CS) 3) Optical Character Recognition (OCR)	The new ANPR system are targeting processing high definition (HD) images rather than of standard definition (SD) images. HD images are able to improve the recognition rate of the ANPR system and also increase the area

	Amira; Xiaojun Zhai.	Recognition System[14]		Four new algorithms are proposed for the OCR stages of a real-time HD ANPR which are based on the feature extraction (vector crossing, zoning, combined zoning, and vector crossing) and template matching techniques.	covered by a single camera. This came with the benefit of reducing the cost since the HD cameras can cover multiple lanes rather than dedicating an SD camera for each lane.
3	Md. Amzad Hossain; Istiaque Ahmed Suyo; Amibath Ray; Md. Ariful Islam Malik; M. F. Mridha.	Number Plate Recognition System for Vehicles Using Machine Learning Approach[15]	2020	A novel technique for vehicle number plate recognition has been developed which is based on the Convolutional Neural Networks (CNNs) and Connected Component Analysis (CCA).	**Result for CCA technique implementation in** :- • Number plate detection – 92.78% accuracy • Character Segmentation – 97.94% accuracy
4.	Nazmus Saif; Nazir Ahmmed; Sayem Pasha; Md. Saif Khan Shahrin; Md. Mahmudul Hasan; Salekul	Automatic License Plate Recognition System for Bangla License Plates using Convolutional	2019	A database which containing the data of Bangladesh Road Trasport Authority (BRTA) standard license plates which attached in front and back of the vehicles.	Incorporated You Look Only Once (YOLO) which is a convolutional neural network (CNN) based object detection algorithm. This model has surpassed the accuracy measure of any ALPR system on Bangla Languages.

	Islam; Abu Shafin Mohammad Mahdee Jameel.	Neural Network[16]			**The advantages of the model** • High accuracy • Speed • Generalization
5	Karthik Hosur; Lohith Jaganathan; Manjunath Ramesh; Nikita Parikh.	Automatic Number Plate Recognition System[17]	2020	Automatic Number Plate Recognition using an efficient OCR engine like Pytesseract along with major and cast libraries of OpenCV for image processing.	**Advantages of the proposed system** ● Able to perform successful and efficient preprocessing on the raw RGB images. ● Able to exploit the high performance and the effectiveness of OpenCV and Pytesseract framework to detect and recognize the license plate of the vehicles. ● Able to correctly determine the number plate based on Indian Number Plate Standards ● Able to successfully extract the information from Government vehicle information database.

6	Andrea Gutai; Sara Havzi; Darko Stefanovic; Andras Anderla; Srdjan Sladojevic.	Optical Character Recognition Methods for Number Plate Recognition : A Systematic Literature Review[18]	2021	An overview of the most common methods used for the optical character recognition in the automated number plate recognition systems, as well as their level of recognition accuracy.	
7	Ahmad Mateen; Muhammad Arslan Anwar; Salman Afsar; Qamar Nawaz; Qasim Yasin; Raim Odinaev; Muhammad Anwar Shahid.	Performance Analysis on Automatic Number Plate Recognition System and Methods[19]	2021	**Several number plate detection and recognition technique** ● Detection for License Plate by Shallow and Deep Learning CNNs in Complex Environments. ● A Robust License Plate Detection and Character Recognition Algorithm Using a BPNN and a Feature Extraction Model. ● Web-Based development of a smart plate number recognition system for fast cars.	**Challenges for ALPR system** ● Brightness issues (Morning, everning, shadows). ● Camera angle, Occlusion of an image. ● Character on the license plate are not complete. ● Blurry images due to vehicle's movements.

8	Abishek Kumar Meena; Abishek Vaishnav; Akshat Govil; Ekta Sharma; Mohd Imran.	Vehicle Number Plate Recognition System Using Matlab : A Histogram Based Approach[20]	2021	A Vehicle Number Plate (VNP) recognition System is a method of mass surveillance that can read vehicle registration number plate in the form of segmented characters by using OCR on the input image. The main focus of this method is the detection of the region of interest and the identification of the number plate.	**Methodology** i. Image Acquisition ii. Gray scaling of image dilation iii. Horizontal and vertical edge processing iv. Passing histograms through the low pass filter v. Filtering out unwanted areas in image vi. Segmentation of the region of interest.
9	Hana Demma; Dr. Mandeep Kaur	Automatic Ethiopian Vehicle Number Plate Detection System using MATLAB[21]	2019	The license plate detection is a very crucial step in the automatic detection and identifying of a license plate. The process of identifying the plate region within the image, which includes image processing principles such as grey scale conversion, dilation, noise filtering, edge filtering, identification of likely	Preprocessing and identification of potential license plate area are two independent aspects of license plate detection. Gray scale conversion is employed in the preprocessing phase, and the licensing area is effectively discovered using horizontal and vertical edge processing.

				areas, and others, is known as plate detection and extraction.	**Process Flow :-** i. Collecting the images of the Ethiopian vehicles and assessing their distinguishing features. ii. Reviewing published related literature in order to select the best algorithm for the project. iii. Selecting MATLAB as the algorithm and explored the software.
10	G. Rajech; K. Chandu; Dr. V. Sucharita; G. Shanmuka Sesha Sai; A. Vinod	Automatic Number Plate Recognition System[22]	2021	Number Plate Recognition (NPR) is a real time embedded system to recognize the number plate of the vehicle. The previous system is utilizing just for the ID of the vehicle meanwhile the new proposed system cumulates both the RFID (Radio Frequency Identification) and NPR.	The shape and cutoff of the number plate were utilized for enhancement purposes. The localization of the number plate is perform by using two methods, which are, the Otsu's method and also the feature based localization method.
11		Automated Number Plate	2021	Automated Number Plate Recognition (ANPR) system is an automated mass	Future work on ANPR system will bring in improvements that enable the

	Emina E. Etomi; Donatus. U. Onyishi.	Recognition System[23]		surveillance method that uses several Digital Image Processing (DIP) techniques and Optical Character Recognition (OCR) on images to read and identify vehicle registration plates.	generated plate number to be used to query a database like MySQL or MongoDB which will allow for a large storage of driver's particulars and vehicle data.
12	Rasika M. Salwan; Piyush N. Dhamande; Kiran P. Chavhan; Amar G. Waghade	Vehicle Number Plate Recognition System[24]	2020	In order to extract the text from the vehicle number plate input image, numerous image preprocessing phases need to be applied. ANPR systems use Optical Character Recognition (OCR) to scan the vehicles number plates, and it can be retrieved whenever required.	**General ANPR algorithms :-** ● Vehicle image capture ● Number plate detection ● Character segmentation ● Character recognition
13	A. Anci Manon Mary; M. Bhuvaneswari; N. Haritha; V.	Design of Automatic Number Plate Recognition System for	2019	The number plate image is taken using the ANPR cameras which then will be processed and will be evaluated by comparing with the database data. The speed limit is monitored using a sensor unit. If the vehicle number plate is	**Advantages of the system**:- ● Fast process ● Accurate results ● Road safety can be increased ● Reduced crime ● Deterring terrorism

	Krishnaveni; B. Punithavathanu	Moving Vehicle[25]		replaced by a stranger, it can be detected using RFID technology.	• More efficient and provides automatic solution
14	Anushruti Gupta; Ayaskant Siddharth; Deepshikha Tyagi; Dr. Krishna Kant Agrawal	Toll Collection using Automatic Number Plate Recognition System[26]	2020	The proposed system is equipped to automatize the collection of Tolls with the help of image processing technique.	The purposed of this system is to save time and mitigate congestion at the toll checkpoints. Additionally, monitoring of any fraudulent behavior which have the possibility of taking place at the checkpoints is made simpler with this system.
15	Abdullah Omer	Vehicle Identifier Recognition System Using Automatic License and Number Plate Recognition[27]	2019	The Optical Character Recognition (OCR) technique is used for the character r. The resulting data is then will be used to compare with the records in the database. In MATLAB, the system is developed and stimulated, and its performance is evaluated using real-world pictures.	**LNPR system advantages:-** • Ease the process of arrival and departure from the parking lot. • Alarm will be triggered if any unauthorized vehicles attempt to enter the premises. • Provide realtime report on the parking state. • Increase the security in the area.

					• Provide numeral statistical reports about the parking and vehicle movement to and from the site. • Ease the inflow/outflow of traffic during rush hours. • Able to broadcast messages for the certain predefined vehicles

2.9 Summary

The research and the explanations from the literature review provide me with some insight on how to develop the proposed system for this project. There are many ways to develop ANPR system, and each of the methods have distinct advantages and disadvantages. The proposed project will be developed with the MATLAB software and using the Image Processing Toolbox and also the Computer Vision Toolbox.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will cover the flows and processes of this Final Year Project from the beginning to the finish. To explain the flow of the process clearly, I will utilize the usage of the flowchart and also use case diagrams. A flowchart is a diagram that depicts the operation of a method, system, or computer diagram. They are used to record, assess, plan, enhance, and convey often complicated processes in a simple and easy diagram in a variety of industries.

The use case diagram, on the other hand, is the primary type of system or software requirements for an undeveloped software program. This diagram will define the intended behaviors of the system rather than the exact technique of achieving it. The most crucial aspect in the use case diagram modelling is that it allows the developer to build a system or software from the standpoint of the end user which will indirectly increase the productivity of it.

3.2 Project Workflow

A project workflow is a painstakingly planned sequence of actions and activities that must be done in order for a project to be finished. It is very important to have a clear and defined order of tasks when involved in project development as it is able to assist the completion of the project more efficiently, save time and also gain a better result. Figure 3.1 below shows the project workflow for the development of the proposed system.

Figure 3.1 Project Flow

3.3 Software

3.3.1 MATLAB Software

The MATLAB software which developed by MathWorks is a programming and numeric computing platform that is able to analyze data, develop algorithms and create models. MATLAB software provides numerous toolboxes which can be downloaded and used depending on the project requirement.

In this project, to develop the proposed system, there are several toolboxes in MATLAB that will be utilized which are the Image Processing Toolbox, Computer Vision Toolbox, and also Computer Vision Toolbox OCR Language Data.

Figure 3.2 MATLAB software logo

3.3.2 OCRTrainer

OCRTrainer is one of the tools in MATLAB software that can be utilized to train an OCR system. It provides a graphical user interface (GUI) that can be used to generate, edit, and train OCR models or dataset without requiring the user to write and code. The OCRTrainer is compatible with a wide variety of character recognition algorithms, including Hidden Markov Model, Neural Network, and Support Vector Machine.

A new OCR model can be generated by using OCRTrainer by specifying the character set, font and training images. Improving the OCR accuracy can be accomplished by utilizing pre-processing techniques such as image enhancement, noise reduction, gray scaling and binarization. Once the model or dataset is trained, the user can use OCRTrainer to evaluate the performance of the dataset on new images and make adjustments if needed.

OCRTrainer is a great tool for building OCR system because it enables the user to easily experiment with variety of different algorithms, parameters, and pre-processing techniques to find the best performing model. It can be used for a wide range of OCR applications and is a good option for researchers and engineers who want to develop OCR systems using MATLAB software.

3.4 Process Model

A process model, generally in graphic form, illustrates the flow of work or activities that contribute to the achievement of a certain objective. Process models are commonly used to depict and evaluate a sequence of actions that happen regularly and on a regular basis. Process models may be used to represent the flow of work among or between individuals

and department within an organization, as well as the flow of operations within a computer system or application.

Process models have a distinct beginning and conclusion, an intended outcome, an order of actions, and alternative outcomes depending on the decisions you make during the process. The goal of the model is to give a representation of the process that enables comprehension, analysis, and decision-making.

3.4.1 System Data Flowchart

The typical ANPR system consists of the following operations: image acquisition, number plate localization, number plate region extraction, character segmentation and character recognition. In Figure 3.3 below, a flowchart shows the sequence of all the operations.

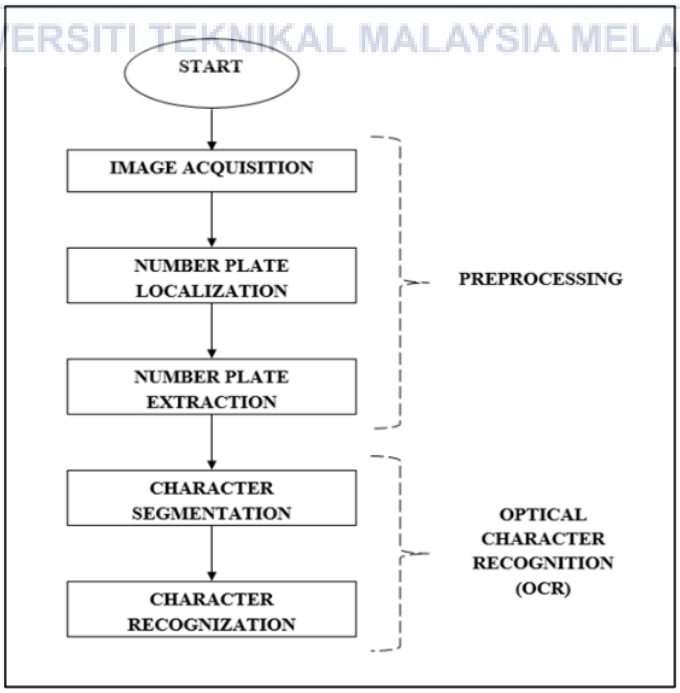


Figure 3.3 Flowchart Diagram for Proposed System

3.5 OCR Dataset Training

OCR training is a process of training a machine learning model to recognize text contained inside photographs or images. The method of training the dataset involves several steps, which are, feeding the model with a dataset of images and corresponding text, and then adjusting and modifying the parameters of the model so that it can accurately predict the text contained in the new images.

OCR training can be broken down into two primary categories: supervised and unsupervised. The supervised OCR training used labelled data, where the text in each image is known, and the goal of the model is to learn to recognize the text in the image. The unsupervised OCR training, on the other hand, used unlabeled data, where the text in each image is not known, and the goal of the model is to learn to recognize the patterns and structures in the images that correspond to text.

Several different techniques, such as Hidden Markov Model, Neural Network, and Support Vector Machines, can be utilized in the process of implementing OCR model. The complexity of the OCR problem and the amount of training dataset influence the algorithm selection.

The OCR training step involves using a dataset of images with corresponding text to teach OCR model to recognize and extract text from image. This dataset is used to train the model to identify patterns and features in the images that correspond to specific characters

or words. The model is then tested on a separate dataset to evaluate its accuracy. Once the model has been trained and tested, it can be used to extract text from new images.

Figure 3.4 OCR training workflow

3.6 Project Phases

In the proposed ANPR system, there are several crucial phases or steps which need to be taken in order to obtain the output as desired and also develop an efficient system. It is very important for the system to follow these phases chronologically as each phase depends on each other's.

ANPR System Phases :-

i. Number Plate Acquisition

ii. Number Plate Localization

iii. Character Segmentation

iv. Character Recognition

3.6.1 Number Plate Acquisition

The first phase of the ANPR system is image acquisition. The input image, which can be in several different formats such as GIF, TIFF, JPG, JPEG and PNG, will be read by

the system by using **imread** function in MATLAB software. This function enables the system to read the input image specified by the user. It is important to note that the quality of the image in this phase will affect the performance of the ANPR system, so the image should be captured under optimal conditions, such as with enough lighting, focus, and resolution.

```
%image acquisition
input = imread("003.png");
```

Figure 3.5 imread function in the system

3.6.2 Number Plate Localization

In the ANPR system, the number plate localization is the process of identifying the location of the number plate on the image, typically by isolation the number plate region from the rest of the image [28]. In this phase, several techniques will be applied to the image in order to gain the region of interest from the input image.

First, the image in RGB format will be converted to a gray scale image by using **rgb2gray** function and applied with gaussian filter function, which is **imgaussfilt**, to reduce any noise in it. Then, the image will be converted to a black and white image by using **im2bw** function before applied with edge detection function which is sobel operator. After that, the image will be applied with morphological dilation function by using **imdilate** function and then the hole in it will be filled by using **imfill** function. Next, morphological erosion function will be applied to the image to gain the region of interest of the number plate by using **imerode** function.

```
%number plate localization
im_gray = rgb2gray(input2);            % rgb to gray
image_gray = imgaussfilt(im_gray,0.5); % reduce noise
im_binary = im2bw(image_gray);         % gray to binary
image = edge(image_gray, 'sobel');     % Edge detection

im_dil = imdilate(image, strel('diamond', 2));   %dilation
im_fill = imfill(im_dil, 'holes');               %fill hole
im_ero = imerode(im_fill, strel('diamond', 10)); %erosion
```

Figure 3.6 Number plate localization phase

3.6.3 Character Segmentation

Character segmentation is an important step in the ANPR system. It is the process of separating the individual characters on the number plate from the background and from each other. In this phase, the system will use the **regionprops()** function to get the bounding box of each character before cropping the number plate region by using **`imcrop`** function. Next, after cropping the number plate region, the image will be applied with **`imcomplement`** function to get an inverse image of it.

3.6.4 Character Recognition

The final phase in the ANPR system is character recognition. Character recognition is the process of identifying and interpreting the individual characters on the number plate which will be achieved in this system by applying OCR techniques. After the previous phase, which is the segmentation process, the system will now have a set of data of the cropped individual image of the desired number plate. This set of data will be used as the input in the character recognition phase.

The input image will be analyzed by the neural network algorithm, and it will process it before finally generating the output of the algorithm as text. The characters need to be

normalized before going through the recognition algorithm. The normalization algorithm is when the character will be refined into a block which has no additional pixels on all sides. The input images in this step need to be in the same size as the database character in order to match the characters with the database. The OCR built-in function in MATLAB will be used in this phase.

3.7 Limitation of Proposed Methodology

The proposed methodology has several limitations that can affect the system performance. Some of the limitations are including the following:

i) Training Data : The performance of the ANPR system is highly dependent on the quality of the training data. If the dataset is not large enough or diverse enough, the model may not generalize well to the new data.

ii) Camera angle and distance : Input image is very essential to the ANPR system because it alone can determine whether outcome of the process. The angle and distance of the image captured can influence the quality of the image, for example, image captured from a very long distance can be too unfocused thus the system could not detect the region of interest.

iii) Lighting and weather conditions : ANPR system can be affected by the changes in the lighting conditions, such as glare, shadows, and reflections, as well as weather conditions such as rain, snow, and fog. All of these can make the characters on the number plate difficult to read.

3.8 Summary

This whole chapter managed to describe all the stages of developing an efficient Automatic Number Plate Recognition System by using the Image Processing Toolbox and Computer Vision Toolbox in MATLAB. The fundamental purpose of the proposed methodology is to obtain a straightforward, less rigorous, and more effective estimation while ensuring that the findings are not considerably less accurate as a result of the decrease in the complexity.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the final results of project implementation, content of the final project, and the analysis of the project.

4.2 OCR Training

Before implementing the proposed system, it is important to train the dataset for OCR. Several commonly used fonts as the number plate font were selected to train as the dataset for this project, which are Arial Regular, Helvetica, and Air Force Regular. OCRTrainer will be used to train the model for ANPR dataset. It will take the selected front as input and return it as a trained OCR dataset.

Figure 4.1 Helvetica font

Figure 4.2 Air Force Regular Font

Figure 4.3 Arial Bold Font

The input image in OCRTrainer and the training for dataset is depicted in Figure 4.4 and 4.5.

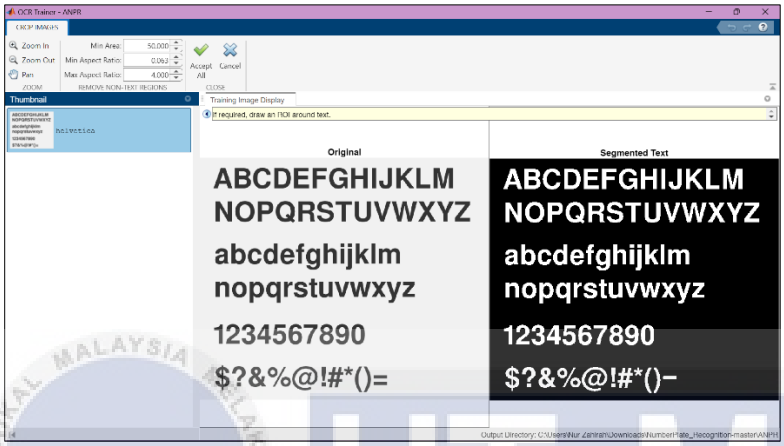


Figure 4.4 Input image in OCRTrainer for training

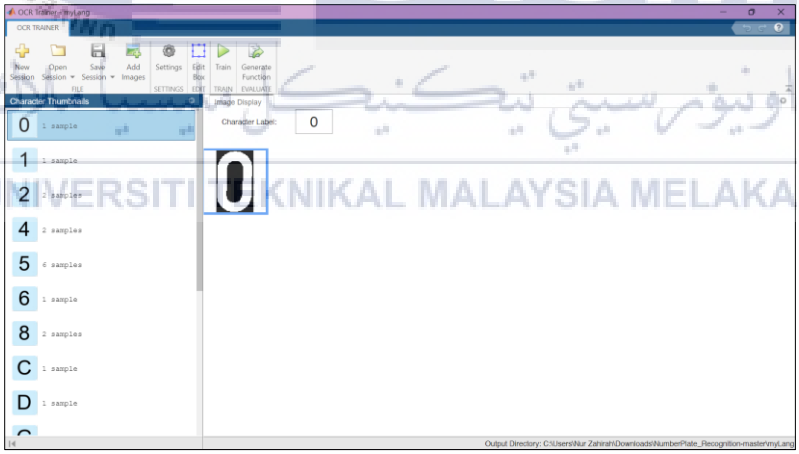


Figure 4.5 Training for the dataset

4.3 MATLAB Implementation

This Automatic Number Plate Recognition system project will be implemented fully in the MATLAB software by using the Digital Image Processing Toolbox and also the

Computer Vision Toolbox. There are several stages in the process which all will be explained below.

4.3.1 Image Acquisition

Image acquisition is the first stage in this project. The program will read the input image given by the user by using the `imread` function. Figure 4.6 shows the input image of vehicle.

Figure 4.6 Original Input Image in RGB

4.3.2 Number Plate Localization

In these stages, the image will go through a few processes in order for the program to be able to locate the number plate location on the input image.

4.3.2.1 Image Grayscaling

The input image by the user is in RGB format. In this stage, the RGB image will be converted into a gray-scale image as shown in Figure 4.7 below.

Figure 4.7 Gray Scale Image

4.3.2.2 Noise Reduction by Gaussian Filter

The gaussian filter will be applied to the gray-scale image in this stage. The purpose of this stage is to reduce the noise in the image so the image will be clearer. Figure 4.8 below shows the image which has already been applied with the gaussian filter.

Figure 4.8 Noise Reduced Image

4.3.2.3 Image Binary

In this stage, the image will be converted to black and white format. The goal of the colour conversion here is to minimize the number of colour scale ranges from the value 0 to 255 to a new range which is 0 to 1. The image from the previous stage will be used to convert into the binary image. Figure 4.9 below depicted the binarized image.

Figure 4.9 Binarized Image

4.3.2.4 Edge Detection

In this stage, edge detection will be applied to the image by using Sobel operator. Figure 4.10 below shows the result of applying Sobel operator to the binarized image.

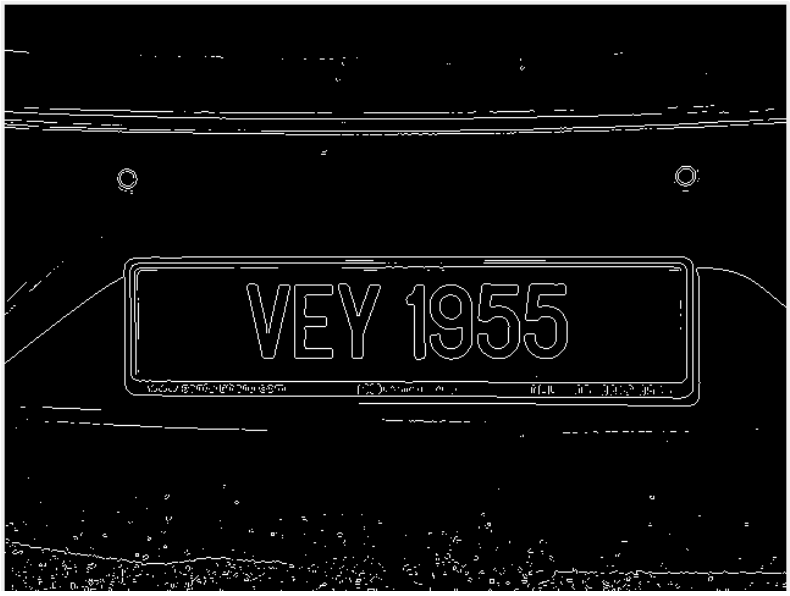


Figure 4.10 Binary image with sobel edge detector

4.3.2.5 Detection of Number Plate Region by Morphological Operation

In this stage, the number plate region will be detected by using the morphological operator. First, dilation operation will be applied to the edge detected image. Then the holes in the dilated image will be filled using the MATLAB **`imfill`** function. Lastly, the number plate region will be detected by using the erosion operation.

The result of dilated image and also filling holes are shown in Figure 4.11 and 4.12 respectively meanwhile the eroded image result is depicted in Figure 4.13.

Figure 4.11 Dilated Image

Figure 4.12 Binary Image with filled holes

Figure 4.13 Eroded Image

4.3.3 Character Segmentation

In this stage, the number plate region will be extracted based on the number plate region detected in previous stage. The Bounding Box Analysis will be used to detect the row and column which indicate the number plate region. Then, the number plate region will be cropped out from the image by using **`imcrop`** function in MATLAB. The cropped number plate image which is in binary will be applied with **`imcomplement`** function in MATLAB which will resulting with an image which is the complement of the colour in the original image. The image in Figure 4.14 and Figure 4.15 depicted the cropped image of the number plate region and the complement number plate image respectively.

Figure 4.14 Cropped image of plate using bounding box

Figure 4.15 Inverse number plate

4.3.4 Character Recognition

The last stage for the proposed system is character recognition. In this stage, the input is the cropped inversed number plate from previous stage and MATLAB will show the license number plate as the output. By using the ocr built in function in MATLAB, the output of this stage would be depicted as Figure 4.16 below.

```
ocrText with properties:

                    Text: '[ VEY1955 ↵↵'
  CharacterBoundingBoxes: [12×4 double]
   CharacterConfidences: [12×1 single]
                   Words: {3×1 cell}
       WordBoundingBoxes: [3×4 double]
         WordConfidences: [3×1 single]
```

Figure 4.16 Output for the project

4.4 Result

Table 4-1 Proposed System Data Result

No.	Input	Preprocessing	Output
1			**VEY 1955** • Accuracy = 100%

2			**JGG 5225** • Accuracy = 100%
3			**JNC 1076** • Accuracy = 100%

4.			**WYR 8054** • Accuracy = 100%
5			**MD4 5311** • Accuracy = 85.7%

6			**JVE 6797** • Accuracy = 100%
7			**WGW 1456** • Accuracy = 100%

8			**WH8 8156** • Accuracy = 85.7%
9			**8RC 400** • Accuracy = 85.7%

10			**WYF S412** • Accuracy = 85.7%

4.5 Analysis

4.5.1 Noise Reduction Threshold

For the noise reduction, the system will use the built-in gaussian filter in the MATLAB. The noise reduction algorithm is the technique of eliminating the noise from the image[29]. This algorithm will reduce the noise by smoothing the entire image except for the areas that near the contrast boundaries.

In the proposed system, the threshold value for the gaussian filter is tested with several different values, which are 0.1, 0.25, 0.5 and 1.0, to find the best value for noise reduction. By comparing those values, the best value for the proposed ANPR system is 0.5. This is because when using the value 0.5, the noise was eliminated well, and it still maintain the necessary detail in the image.

Table 4-2 Comparison between the threshold value for noise reduction

	Input Image		**Conclusion**

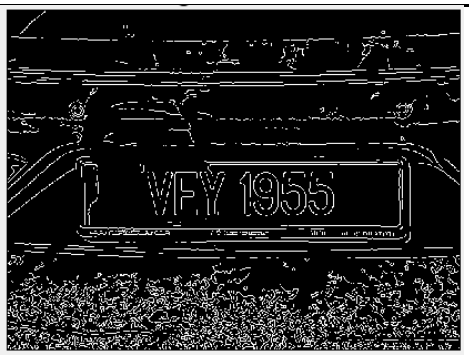
Threshold value	**0.1**		When using 0.1 threshold value, the function removes too little amount of noise in the image thus cause the edge detection is failed.
	0.25		When using 0.25 value as threshold for gaussian filter, the function will reduce little noise, so the image did not really clear.
	0.5		When using 0.5 threshold value, the function only remove moderate amount of noise in the image and the image is still clear.
	1.0		When using threshold value 1.0, the function will reduce too many pixels in the image and cause the image to become blurred.

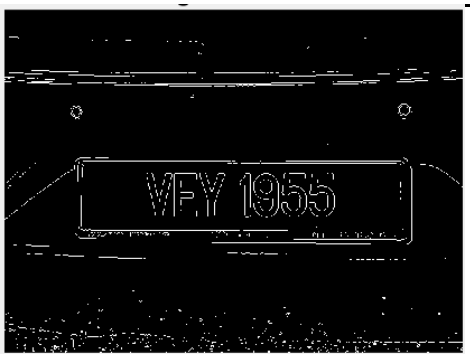
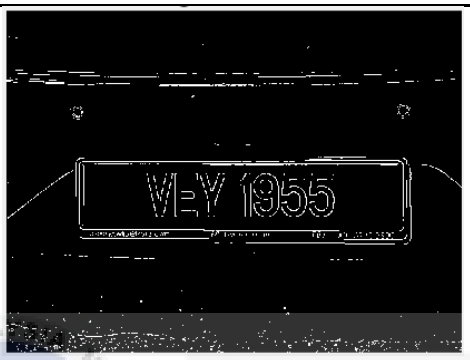
4.5.2 Edge Detection

Edge detection is a process in image processing that is used to identify boundaries of objects within an image [30]. In MATLAB, there are several built-in edge detection operators that can be used, including the Sobel operator, the Prewitt operator, Roberts operator and the Canny operator. Edge detection is a vital step in ANPR system because it can help determine the region of interest of the number plate in the image.

To choose the suitable edge detection operator for this system, 20 images were used as dataset to compare the outcome of each edge detection operator. The selected operator to be tested are Canny operator, Prewitt operator, Roberts operator and Sobel operator.

Table 4-3 Comparison between edge detection operator

	Input Image		**Conclusion**
Edge Detection Operator	**Canny**		For Canny operator, the percentage of successful edge detection in the dataset is 96.2%.

	Prewitt		For Prewitt operator, the percentage of successful edge detection in the dataset is 91.6%.
	Roberts		For Roberts operator, the percentage of successful edge detection in the dataset is 86.2%.
	Sobel		For Sobel operator, the percentage of successful edge detection in the dataset is 97.7%.

Based on the comparison in the table above, the most suitable edge detection operator to use in the proposed system is Sobel operator. This is because Sobel operator has the highest percentage of successful edge detection in the dataset among the other edge detection operators which is 97.7%.

4.6 Summary

As a conclusion, this whole chapter discusses the data analysis for the system and also the discussion for the output of the results for the development of ANPR system. The ANPR system is built in the MATLAB with the Image Processing Toolbox and also Computer Vision Toolbox. The selected edge detection operator for the system is the Sobel operator meanwhile the threshold value for the gaussian filter is 0.5. The accuracy for the ANPR system that is being developed is 94.28%. The inaccuracy of the output is the result of not accurate region of interest. Thus, overall, the proposed system is successfully being developed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Automatic Number Plate Recognition (ANPR) system is a technology that is able to read and recognize vehicle number plates from image by utilizing optical character recognition algorithm. This system is developed in the MATLAB software with the help of several toolboxes like Image Processing Toolbox, Computer Vision Toolbox, and Computer Vision OCR Language Data Toolbox.

The proposed system operates by reading the input RGB image of the vehicle registration number plate before converting it into a gray-scale image. Then, the noise reduction by using gaussian filter will be applied to the input image in order to enhance the image. Then, the image will be converted into binary image and then edge detection will be applied to it by using Sobel operator. Morphological operator will be applied to the image to locate the number plate region before it is undergoing the character segmentation process. The cropped image of the number plate region will be applied with the OCR built-in in the MATLAB which already being trained with several dataset. The system then displays the output of the program which is the license number plate.

The accuracy for the ANPR system that is being developed is 94.28%. The inaccuracy of the output is the result of not accurate region of interest. Thus, overall, the proposed system is successfully being developed.

5.2 Future Works

The developed system in this project has so much room for improvement as to be able to perform more accurately and efficiently. Several potential areas of future work for ANPR system are including the following:

i) Multi-language support [31] : ANPR systems can be improved by developing techniques that enable the system to recognize the number plates written in variety of languages, which would make it more practical in regions where numerous different languages are spoken.

ii) Security and Privacy : Security and privacy is a growing concern nowadays, therefore ANPR system can be improved by developing techniques for secure storage and transmission of data and preventing unauthorized access to the data.

iii) Mobile ANPR [32] : ANPR system can be improved by developing a mobile version of the system that can be used on smartphones and other mobile devices. This would allow users to take images of the number plates and perform the recognition tasks on the go.

iv) Real-time processing : ANPR systems can be enhanced by developing techniques for real-time processing of video streams. This would enable the system to detect number plates in real-time as the vehicles pass by.

v) Robustness to varying lighting and weather condition [33] : The ANPR system can improved by developing techniques that can make the system more robust to varying lighting and weather conditions, such as glare, shadows, and reflections.

vi) Integration with other systems : ANPR system can be integrated with other systems such as traffic management systems, toll systems, and parking management systems to provide more comprehensive solutions.

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APPENDICES

Appendix A MATLAB coding

```
%ANPR System

%image acquisition
input = imread("003.png"); %read image
input2 = imresize(input, [480 NaN]); %resize

%number plate localization & extraction
im_gray = rgb2gray(input2); % rgb to gray
image_gray = imgaussfilt(im_gray,0.5); % reduce noise
im_binary = im2bw(image_gray); % gray to binary
image = edge(image_gray, 'sobel'); % Edge detection

im_dil = imdilate(image, strel('diamond', 2));
im_fill = imfill(im_dil, 'holes');
im_ero = imerode(im_fill, strel('diamond', 10));

%character segmentation
im_struct=regionprops(im_ero,'BoundingBox','Area', 'Image');
area = im_struct.Area;
count = numel(im_struct);
max= area;
BoundingBox = im_struct.BoundingBox;
for i=1:count
   if max<im_struct(i).Area
       max=im_struct(i).Area;
       BoundingBox=im_struct(i).BoundingBox;

   end
end

image1 = imcrop(im_binary, BoundingBox); % crop the number plate
imgcompl=imcomplement(image1); % inverse image colour
imgfilt=bwareaopen(imgcompl,150);

%character recognition
output= ocr(imgfilt);
disp(output);

figure(1)
subplot(2,3,1);
imshow(input);
title("Input Image");

subplot(2,3,2);
imshow(image_gray);
title("Grayscale Image");

subplot(2,3,3);
imshow(im_binary);
title("Binary Image");
```

```
subplot(2,3,4);
imshow(image);
title("Edge Detection");

subplot(2,3,5);
imshow(image1);
title("Bounding Box");

subplot(2,3,6);
imshow(imgfilt);
title("Bounding Box");
```