Localization and Recognition of a Myanmar License Plate Based on Partially Cut Character Structure

by

Myint Myint Htay

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ABSTRACT

The application of automatic systems is being promoted in Myanmar. At the same time, the number of vehicles including private cars, taxies and buses are increasing day by day, automatic vehicle security systems are necessarily important to increase national security in both public and private places. License Plate Recognizing (LPR) plays an essential role in automatic vehicle access control systems which are popularly used for private and public security today. LPR is based on image processing technology. Therefore, to develop a reliable LPR system for recognizing Myanmar vehicle license plate is currently in demand.

In this work, an image processing method for localizing and recognizing Myanmar vehicle license plate is developed. It consists of three main steps; license plate localization, character segmentation and character recognition. The localization of license plate is performed based on Euler number and license plate aspect ratio. Then, boundary tracing method is used for character segmentation. Finally, the character recognition is implemented based on partially cut character structure.

The performance of proposed license plate recognition method is tested for real field Myanmar vehicle images including front view, back view, skewed view, near view and far view. The proposed method shows a reliable performance by detecting even in skewed plates without skewness correction. Thus, this work contributes a LPR system which is practically useful in automatic vehicle security system in Myanmar.

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CHAPTER 1: INTRODUCTION

This chapter introduces the importance of image recognition, the automatic vehicle security (identification) system, and the concept of License Plate Recognition (LPR) system.

1.1 Importance of Image Recognition

With the help of super power computers, image processing is getting into a wide application, and it becomes a popular and essential technology in this modern age. Image processing helps us to see and communicate distinct spatial or temporal patterns of the physical world (from daily life recorded pictures to essential medical images such as X-ray, sonogram image) as well as to make optimal decisions and right actions. Thus it has given a great impact on our modern society. Currently, the application of image processing can be found in many different fields such as national and organizational security, biomedical science, remote sensing, robot and computer vision, manufacturing, agriculture and food quality control.

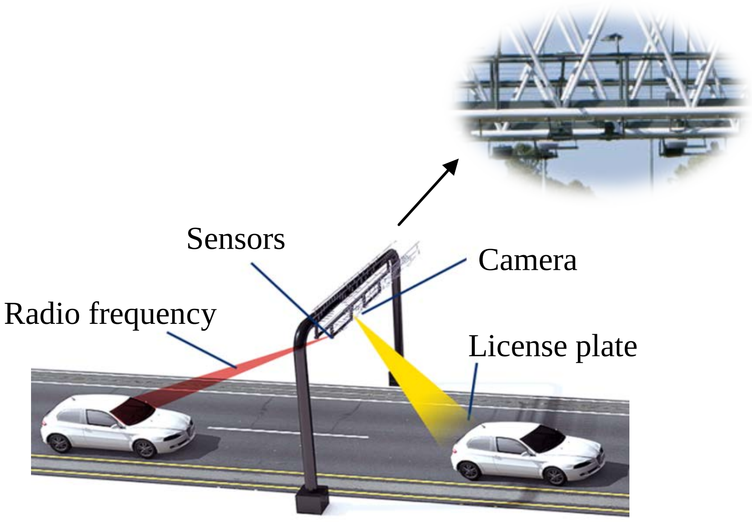
Here, image processing is importantly being used for two principal objectives. The first objective is the improvement of pictorial information for human interpretation. For example, the quality of medical images is enhanced so that the physicians can easily see and understand the region of interest. The second objective is to process a scene data for an autonomous machine vision, which is termed as image recognition. The obvious instances are recognizing human faces, eyes or fingerprint by using automatic recognizing systems in immigration centers to assist national security.

For the global economy competition, today most of the traditional (or manual) systems have been replaced with the automatic (or intelligent) systems in order to reduce man power requirement and cost, to increase working hours and the quality of performance. Some of those automatic (or intelligent) systems are based on vision system to make decision and to perform task. In such system, the manipulator must see and understand the object in the physical world, in which image recognition becomes mandatory. In this regard, the importance of image recognition increases in parallel with the increased deployment of automatic recognition systems and automatic machines.

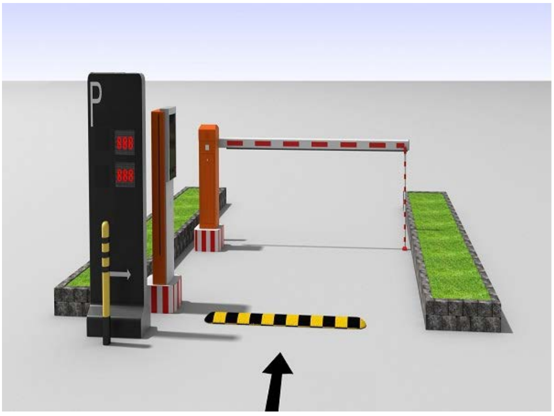
1.2 Automatic Vehicle Identification System

Today, automatic vehicle identification systems have been increasingly used in both private and public security in order to reduce man power (labor) requirements and cost, increase working hours and avoid unwanted error in handling. Here, the application of automatic vehicle identification in controlling vehicle access in both public and private places is becoming more and more popular. As shown in Figure 1-1, automatic vehicle identification systems are installed at the toll gate on highways, traffic poles and private security gates.

A typical vehicle identification system shown in Figure 1-2 consists of an optical sensor to detect car arrival, a video camera to take the front or back view of the car arrived, a processing and control unit to control the gate. The working principle of automatic vehicle identification system is as follows. When the optical sensor detects a vehicle, it signals the video camera to take the front view of the car in which the license plate must be included. The images taken are immediately transferred to the processing unit. Then, the processing and control unit extracts the information of the vehicle, especially license plate, by using license plate recognition (LPR) image processing algorithm and records the information for further action. If it is at a security or tollgate, it decides whether it should open the gate or not.



(a)



(b)

Figure 1-1 Automatic vehicle identification systems at

(a) public place, (b) private place

Here, it can be understood that the reliable performance of an automatic license plate recognition system is critically inflected by LPR system. Although, the sensors and the cameras are working well, the image can be degraded due to the lighting condition of environment and the position of camera and vehicle. Thus, precise and flexible LPR system must be integrated so that the system can extract vehicle information from various image situations. Thus, it is clear that LPR plays an essential role in automatic vehicle identification system.

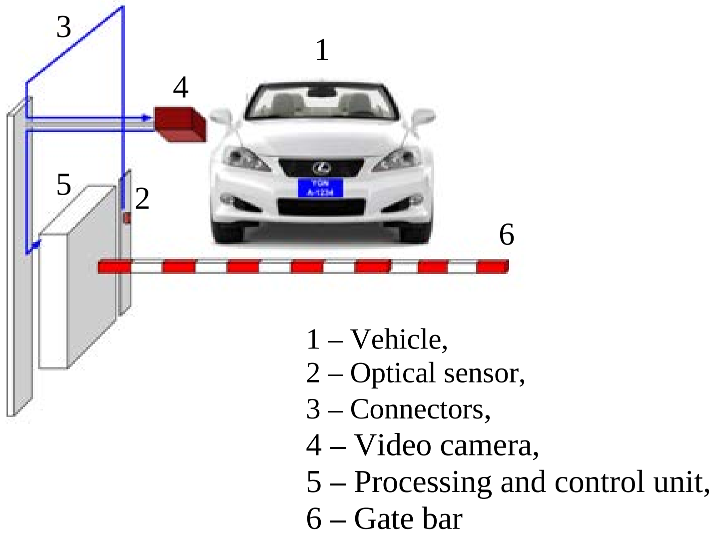


Figure 1-2 Concept of a typical automatic vehicle identification system

1.3 License Plate Recognition (LPR) System

Generally, LPR includes the following three main steps; localizing license plate, segmentation of plate characters and recognizing of each character [1] is shown in Figure 1-3. Here, low level image quality enhancement increases the visibility and/or sharpness of the objects in the car. It is performed if the raw image provided by camera does not perfectly fulfill the quality requirement. Thus, it is an optional step. Then the high level image quality enhancement does skew detection and modification if the images are not perfectly straight. It is also an optional step if the system is well prepared and if the images taken are perfect.

In LPR system proposed in this work, license plate localization is performed based on license plate aspect ratio and Euler number. Then, boundary tracing method is used for character segmentation. The last step, character recognition is based on partially cut character structure.

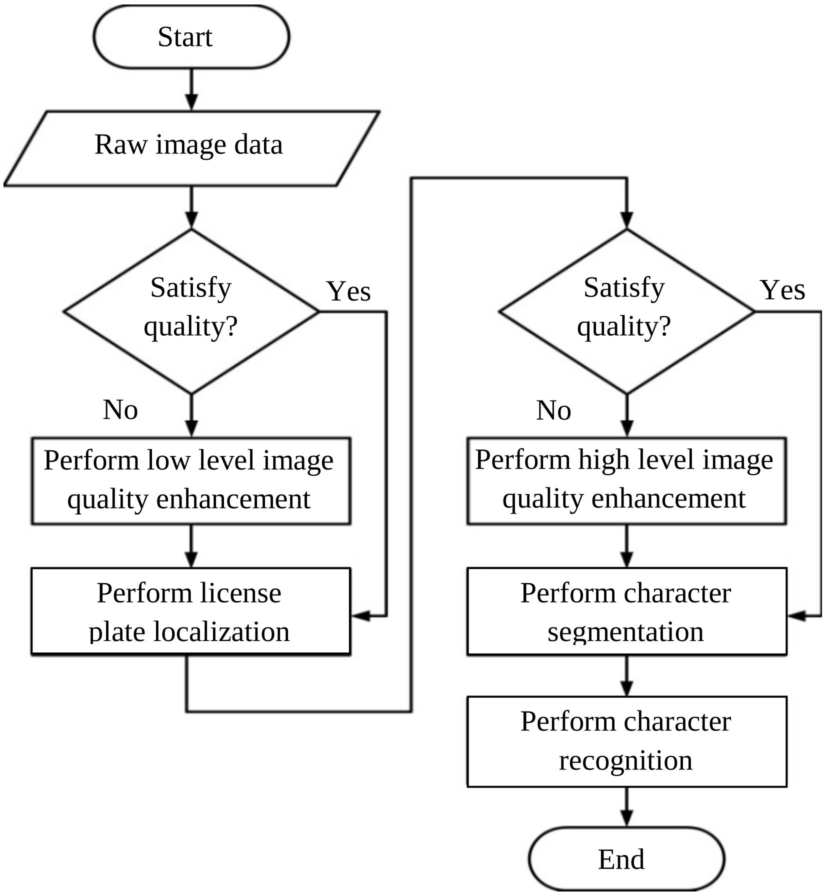
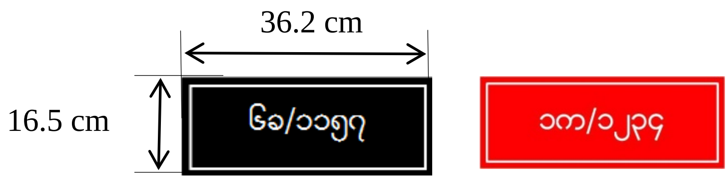


Figure 1-3 A typical LPR system

1.4 License Plates Used in Myanmar and Need of LPR

Currently, Myanmar is trying to develop modern technologies in different sectors to improve the living standard of its people. Thus, the application of automatic system is being promoted in Myanmar. At the same time, the number of vehicles including private cars, taxies, and buses are increasing day by day, automatic vehicle security systems are necessarily important to increase national security in both public and private places. Therefore, to develop a reliable LPR algorithm for recognizing Myanmar car license plate is currently in demand.

There are four different types of license plates used in Myanmar according to its vehicle laws. A sample for some type of license plate is shown in Figure 1-4. All types of license plate have the width of 36.2 cm (14.25 inches) and the height of 16.5 cm (6.5 inches). There is a white color line along the peripheral of the plate, which makes a white boundary line of the plate. All the characters are in white color. The difference between each other is the background color of the license plate. Black color is used for private (family) cars, red color for taxies and buses, yellow color for vehicles of religion persons (monks), and blue color for foreigner tour buses.



(a) (b)

Figure 1-4 License plates in Myanmar (a) private car, (b) taxi

CHAPTER 2: LITERATURE REVIEW AND PROBLEM STATEMENT

In this chapter, a survey on previous works that concerned different LPR algorithms is performed. And then, the problem that needs to be solved is addressed. Finally, the main goal and objectives of this research are described.

2.1 Previous Researches on LPR System

In the literature, there have been a number of works concerned with three mains steps of LPR system. Also, there have been some attempts that focused on optional steps of LPR process. For examples, the authors of [2] and [3] proposed super-resolution method to enhance the image quality before character segmentation. Then, Fang et al.[4] presented an image-deblurring method for blurred images of license plates.

2.1.1 Related works on localizing license plate

Indeed, among three main steps of LPR, to accurately detect the location of a vehicle license plate from the image obtained is the key step [5] because it is the first and the most responsible step for the correctness in the following steps. If the result from the first step is not precise or wrong, it will consequently give difficulties or affect the results in subsequent steps. Thus, the developers of LPR system for practical use usually face a great challenge at the first step. For this reason, the authors of many previous researches have proposed many different solutions to cope with challenges raised in the first step of LPR. Thus, some selected works that were concerned with localizing license plate are reviewed as follows.

Guanglin and Yali [6] used color pixel counting method to localize the license plates. In that method, the number of interested color pixels are counted and recognized as plate region. This method is straightforward if all car license plates used in a particular nation have only one background color. However, it will not be reliable, if there are different types of license plates and different plate colors. Haneda and Hanaizumi [7] used both color pixel values of the image and known aspect ratio of targeted license plate to recognize the region of license plate. Here, the aspect ratio means the ratio of height to width of the license plate. The aspect ratio of vehicle license plate depends on the vehicle law of corresponding region (country). Then, the same procedure was applied in [8]. Also, in most works of [10, 11, 12, 13], the methods used to localized license plate were based on detecting plate color pixel, counting color pixel, extracting edges of the detected objects, performing morphological operation to find reasonable objects and comparing with known aspect ratio of targeted license plate.

Sachenko, and Markowsky [9] applied Hough transform method to search the license plate in the recorded image. In this method, at first, the intensity image needs to be converted to binary image in which the foreground (white) is 1 and the background (black) is 0. Then, horizontal and vertical lines are extracted from coordinates of foreground pixels. Then, the possible rectangle shape is reconstructed by using horizontal and vertical lines extracted. Finally, the aspect ratio (width to height ratio) of rectangle shape detected in image is compared with practical aspect ratio of license plate to confirm the region of license plate in the image. However, this method consumes a much time and it is not reliable when the license plate is skewed or deformed. After this survey, it can be noticed that the most essential parameters in localizing license plates are the color and the aspect ratio of the license plate.

2.1.2 Related works on character segmentation

After extracting license plate, the next task is to segment each character contained in the plate. Indeed, there are many methods to segment the characters from the plate. Guanglin and Yali [6] used the vertical projection method in which the character pitch and aspect ratio are used to segment the character. However, this method cannot be applied if the license plate is poorly is deformed. Then, Cheng and LI Shao-Fa [8], the objects (characters) in license plate are first detected. Then, the bottom, upper, left and right boundaries of each detected object was examined. Finally, each character was extracted by using bounding box. The other method used in Obeid and Zantout [15] is the pixel counting method. In this method, the total number of white and black pixels is counted for each column of the binary matrix that represents the license plate. Then, the boundary of between each character can be recognized by searching the column whose all pixels are black.

From these methods that have been surveyed, it is realized that the bounding box method is more reliable than the others.

2.1.3 Related works on character recognition

Character recognition is also a very tricky step in LPR. The most widely used method is template matching method in which the minimum distance between the features of trained image (templates) and tested image is found out [13]. The template that gives the minimum distance with tested image represents that tested image. This method is simple but frequently used in previous works [6]. In the work of Lee et al.,[11], a template matching and postprocessing techniques are used to recognize the character. Then, in some other works [8, 10] used neural network in which the input image has to pass multiple layers in which properties of trained characters are set. The method is tolerable to noise contained in the image.

Obeid and Zantout [15] and Wanniarachchi [16] presented line processing algorithm to recognize the character in which each character is divided into many different parts by means of vertical and horizontal straight lines. Then the black and white pixels are counted for each vertical and horizontal line to classify each character. The authors stated that their proposed algorithm was 100% reliable. Then, Ghasrodashti and Yazdi [17] proposed binary Time Delay Neural Network (TDNN) to recognize zoomed characters. With their approach, 50 license plates were tested and 70 % of them are well recognized. In other algorithm proposed by Yilmaz [18], neural network and image correlation (a hybrid method) is used to recognize the characters. First they recognized the character by using an image correction factor. If the correlation factor is less than 0.5, they used neural network.

2.2 Problem Statement

There have been a number of works that proposed LPR system for recognizing car license plate. Generally, most LPR systems are concerned with the color, structural dimensions of the corresponding license plate and the features of the characters contained. Thus, it is clear that a generalized LPR system that is flexible (applicable) to recognize license plates from all over the world cannot be developed. The reason is that different countries have different vehicle laws, which make different license plates in terms of color, size and characters. It means that a particular region or nation requires a particular specialized LPR system to recognize the license plates in that region.

Besides, there are different license plates even inside Myanmar as described in section 1.4. Thus, no existing LPR system is applicable in Myanmar. Similarly, a reliable and efficient LPR system is cortically in demand in Myanmar. Therefore, the aim of this research is to develop an efficient LPR system for recognizing license plates used in Myanmar.

2.3 Goal and Objectives

With the tremendous increment of motor cars, automatic vehicle identification systems with efficient LPR are becoming important. Thus, researches pertaining to LPR are crucially in demand.

The main goal of this research is to develop a robust LPR system which can be used as a part of automatic vehicle identification systems in Myanmar by implementing the following research objectives:

(1) To develop an image processing algorithm to localize target region.

(2) To develop an image processing algorithm to segment the objects.

(3) To develop an image processing algorithm to recognize characters.

(4) To test the newly developed LPR system with real filed images of vehicles in Myanmar.

This research contributes an efficient LPR system for automatic vehicle identification systems in Myanmar.

2.4 Scope and Limitations

This research will be in the scope of image processing and recognition of object and characters (number and alphabet). In this research, different license plates used for private cars, city taxies in Myanmar are considered. Although, there are many different types of license plates which are currently being used in Myanmar, some types are very rarely used.

The LPR system was implemented using MATLAB software from Math Works. During this research, the following reasonable assumption will be made.

(1) The system will be used in public car parking in Yangon.

(2) The positions of camera and the car coming to park are well prepared to have a straight orientation during capturing the image. If the car is not in a right position, the system will sound an alarm until it reaches in right position.

(3) The dimensions of the car and the plate in the image acquired by a typical toll gate camera do not vary more than about 15% according to the observation.

(4) The images sent to the processing unit are color images.

CHAPTER 3: SYSTEM OVERVIEW

In this chapter, the concept of a new license plate recognition system is briefly described.

3.1 LPR System

The block diagram of LPR system that is developed in this research is shown in Figure 3-1. First, a randomly selected raw image will be inputted to the system. Some image processing processes are optionally performed if image quality enhancement is required.

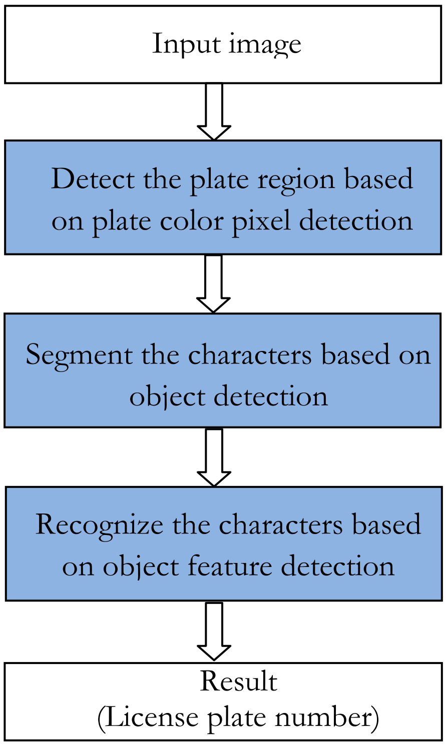


Figure 3-1 Block diagram of newly developed LPR system

3.1.1 Plate region detection

To extract the license plate, the preknown license plate color (black, red, yellow, blue) are detected. Then detected color pixels (black, red, yellow, blue) are changed to foreground color 1 (white) and the other pixels are set as background 0 (black) color as shown in Figure 3-2 (a)-(b). The binarylization method for producing binary image is explained in Chapter 4.

(a) (b)

Figure 3-2 Intensity image and binary image of a car

Then, filtering is made to remove impossible regions (a very small and a very large region). The detailed description of filtering strategy can be seen in Chapter 4. Then candidate regions from binary image are detected with plate color pixel detection method. Then, the license plate is extracted by using *k*-Nearest Neighbors (*k*-NN) classification method as shown in Figure 3-3. The *k*-NN classification method is discussed in Chapter 5.

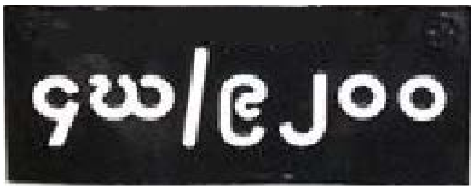


Figure 3-3 Extracted license plate

3.1.2 Character segmentation

After extracting the license plate, the characters in the license plate are segmented into single individual character as shown in Figure 3-4. The characters are segmented without disturbing their location in the plate. Each character becomes one individual image. For the character segmentation bounding tracing method is used. It is presented in Chapter 6.

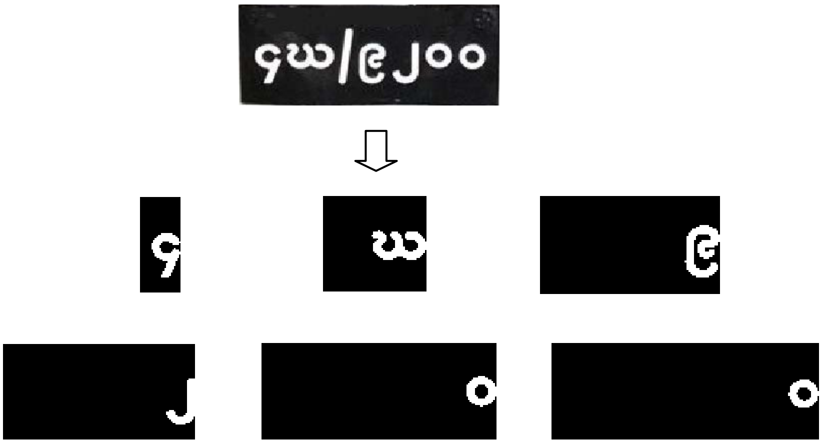


Figure 3-4 Segmented characters

3.1.3 Character recognition

Then, the morphological features of each character are extracted. In the features extraction process, partially cut structures of each character are used. The “***Partially cut character structure***” is a new method developed for this research and is described in Chapter 6. After extracting features (full structure, upper cut, bottom cut, left cut and right cut of each character), *k*-NN classification method is used to recognize each character. Finally, the whole license plate is recognized and the information is automatically saved as equivalent character shown in Figure 3-5.

Figure 3-5 Result of license plate recognition

CHAPTER 4: DETECTING CANDIDATE REGIONS

In this chapter, methods used to detect and collect all possible candidate regions of license plate in an image are acquired. To detect all possible regions, first it is necessary to convert the intensity image into the binary image. There are many approaches to convert intensity image to binary image. However, for this research, color intensity based binarilization method is used because it is more straightforward if the color of targeted object is pre-known. Then, a filter process is performed to collect the candidate regions from all possible regions.

4.1 Binarylization Method

For producing binary image of inquired intensity image, RGB (Red, Green, and Blue) values of targeted object are used as threshold values. For this case, the targeted object is the license plate used in Myanmar. The background color of the plate is black or red and it is dominant color in the plate. The black color has RGB values of (0, 0, 0) and the red color has RGB values of (255, 0, 0). However, it is enough to set the threshold values of black color license plate as (50, 50, 50) or red color license plate as (100, 50, 50) because there can be some variation of color due to the resolution of image or illumination. The color (*R*, *G*, *B*) value of any pixel that agrees with the following relationship, the color is set to foreground color (1), otherwise the pixel is set as background color (0). The pixel coordinates of black and red license plates are given below:

$$\begin{array}{l} I(x,y)=1 \\ I(x,y)=1 \\ I(x,y)=0 \end{array} \begin{cases} if\ \ R<50\ and\ G<50\ and\ B<50 & (Black) \\ elseif\ \ R>100\ and\ G<50\ and\ B<50 & (Red) \\ otherwise \end{cases} \tag{4-1}$$

where,

$I(x,y)$ = Pixel at x, y coordinates and

$\{R, G, B\}$ = Color value of red, green and blue.

Here, the plate region can stand alone even if the plate color and car body color is the same because the original license plate has white boundary which appears as black color in binary image as shown in Figure 4-1. The plate background color becomes white and the characters inside it and its boundary become black. Thus, it becomes an isolated region or individual region in the image. Therefore, it is possible to detect that region as an object.

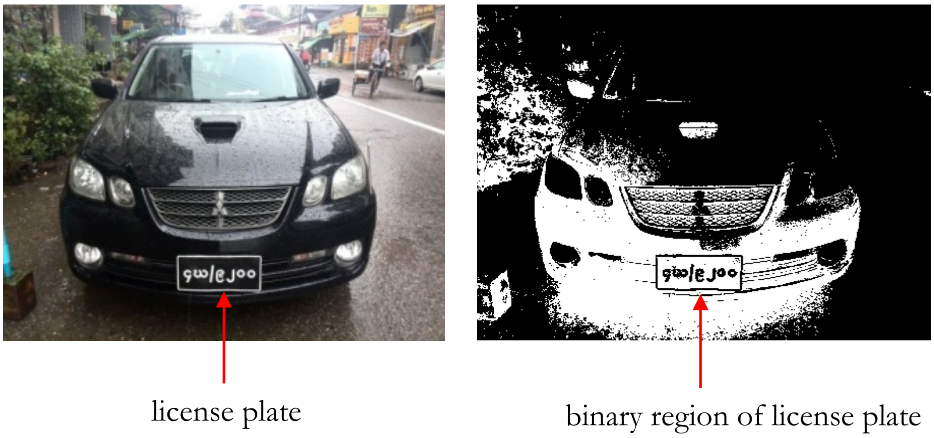


Figure 4-1 Intensity image and binary image of a car

4.2 Filtering Method

After converting intensity image to binary image, all individual white regions are extracted and filtering processing is performed to filter impossible regions. First, Euler number of each region is inspected. According to the number of characters in Myanmar license plate, the Euler number should be less than -5. Here Euler number is defined as the number of object (the license plate background) minus the number of holes (character images in the license plate) in that object. As shown in Figure 4-2, the characters in license plate become holes in producing binary images.

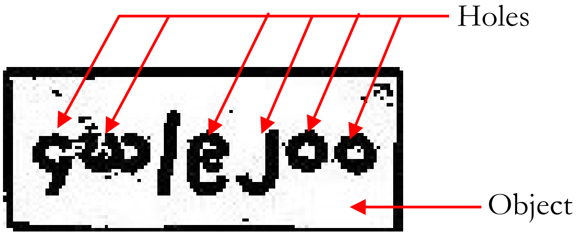


Figure 4-2 Object and holes in binary image of license plate

The other parameter used to filter impossible regions is the area of each region (object) in the image. The area of a region (object) is the total number of pixels in that region (object). In this case, the regions (objects) that are smaller than one-hundred of image area and larger than half of image area are filtered out. The reason is that the size of license plate will not be too small or too large in a car image if the car is taken photo from a distance of about 3m to 5m from the camera at security gate. Thus, the following filtering equation is developed.

$$\begin{matrix} \Omega_{candidate} = 1 \\ \Omega_{candidate} = 0 \end{matrix} \begin{cases} if \ \dfrac{A_{im}}{100} < A_{\Omega_i} < \dfrac{A_{im}}{2} \ and \ En < -5 \\ Otherwise \end{cases} \quad (4\text{-}2)$$

where,

$\Omega_{candidate}$ = Selected candidate region of license plate

A_{im} = Total area of the image

$A_{\Omega i}$ = Area of individual detected region

En = Euler number of detected region

The advantage of this filtering concept is being able to detect the license plate although the plate is skewed, deformed and if there are some plate-like objects around it. As shown in Figure 4-3, an image with three objects including three plates is tested. All are similar to each other and only the license plate is skewed and deformed. However, with the proposed filtering method, from three regions, only the targeted plate region is extracted correctly as a candidate region. After all candidate regions have been detected, their foreground and background are reversed.

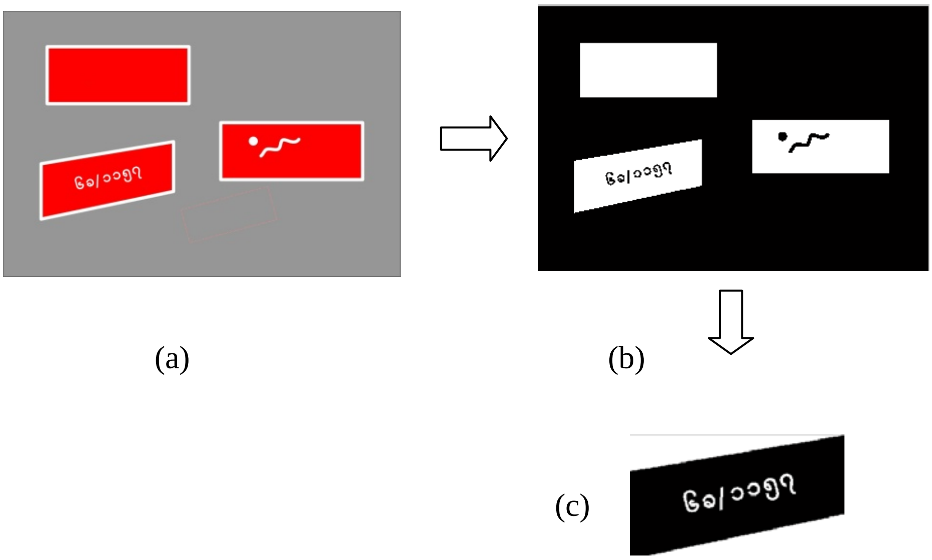


Figure 4-3 Candidate license plate (a) color image, (b) detected regions, (c) candidate region

CHAPTER 5: EXTRACTING LICENSE PLATE

After collecting candidate regions for the license plate, this step is to extract exact license plate from candidate regions. Here, k^{th} Nearest Neighbors (*k*-NN) classification method is used to classify the license plate. Thus, *k*-NN classification method is discussed in this chapter.

5.1 k^{th} Nearest Neighbours (*k*-NN) Classification

The *k*-NN classification method is widely used for classification purpose. It is based on the concept of the most nearest distance between the learned features and query features. The detailed concept of the *k*-NN classification method can be as follows. Let’s say, there is an area in which there are groups of different symbols (+, × and -). Then, if a random query point q is set in that area, the question is "*What symbol will be found*?”. To answer this question, the distance between coordinates or features of each symbol and query point must be calculated. Then, the query point would be the symbol that gives the smallest (nearest) distance. That distance is called Euclidean distance and it can be calculated as follows.

$$d_i = \sqrt{\sum_{i=1}^{n} \left(X_i - Y_i\right)^2} \tag{5-1}$$

where,

d_i = Euclidean distance between learned feature and query feature

X_i = i^{th} learned feature or coordinate

Y_i = i^{th} query feature or coordinate

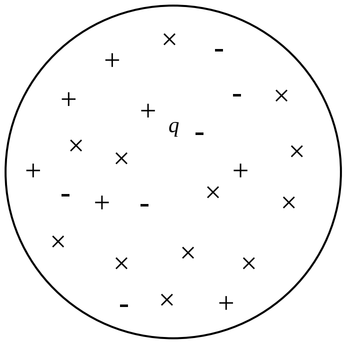


Figure 5-1 Symbols in an area

Indeed, in classification, the value of *k* should not be an even number (2, 4, 6 and so on) because there is no average value in this classification. For example, as shown in Figure 5-1, the query point *q* is close to symbols + and -. Thus, it has equal number of votes and no classification can be done. Hence, the value of *k* should be 1, 3, 5 or other odd numbers in classification. The class of *q* will follow the type that has larger number of votes. However, the value of *k* can be 3 or more only when there are many objects of the same type in the interested region as shown in Figure 5-1.

For the case of license plate, the license plate is single object appeared in car image as shown in Figure 5-2. Thus, the value of *k* must be 1.

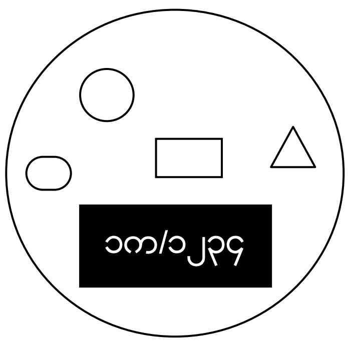


Figure 5-2 Sample license plate in an area

5.2 Learned Features

For extraction of a license plate by using k-NN classification, the learned (trained) features are needed. Thus, only one learned feature is used. It is the aspect ratio of the license plate (width to height ratio) is shown in Figure in 5-3.

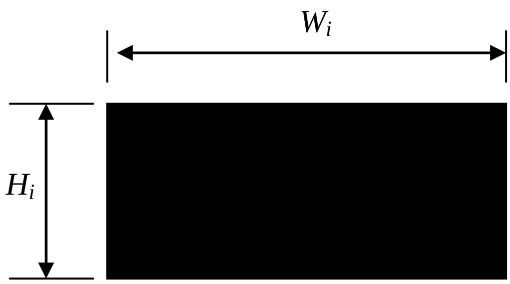


Figure 5-3 Aspect ratio of candidate region

$$AR_i = \frac{W_i}{H_i} \tag{5-2}$$

where,

AR_i = Aspect ratio of candidate region

W_i = Width of candidate region

H_i = Height of candidate region

Myanmar license plate has a width of 36.2 cm (14.25 inches) and a height of 16.5 cm (6.5 inches). Thus, the aspect ratio of targeted license plate is 2.3. The aspect ratios of all candidate regions are calculated first. Then, k-NN classification method is used to extract the exact license plate.

CHAPTER 6: CHARACTER SEGMENTATION AND RECOGNITION

In this chapter, the license plate character segmentation and recognition are presented. Here, there are many methods for both character segmentation and recognition. For example, pixel counting method is a very straightforward method for character segmentation. However, it is useful only when the text appearance is very perfect and not skewed. Then, the template matching method is widely used for character recognition. The drawback of that method is that it needs a long processing time. For this reason, boundary tracing method for character segmentation and feature matching method for character recognition are presented and used in this work. Here, learning (trained) features are based on partially cut character structure.

6.1 Character Segmentation

After extracting the license plate, the image is converted to binary image. Here, the plate background color is black and the foreground color (character color) is white. Then, each character is segmented by using boundary tracing method. In boundary tracing method, the boundary coordinates of each character is recorded as each indicial pixel group as shown in Figure 6-1. Thus, the *upper, bottom, left and right* boundary of an object can be easily evaluated as follows:

$$\left.\begin{aligned} LS &= \min(X_p) \\ RS &= \max(X_p) \\ US &= \max(Y_p) \\ BS &= \min(Y_p) \end{aligned}\right\} \tag{6.1}$$

where,

LS, RS = Left and right margins of the object,

US, BS = Upper and bottom margins of the object,

X_p = Vector of X-coordinates of boundary pixel, and

Y_p = Vector of Y-coordinates of boundary pixel

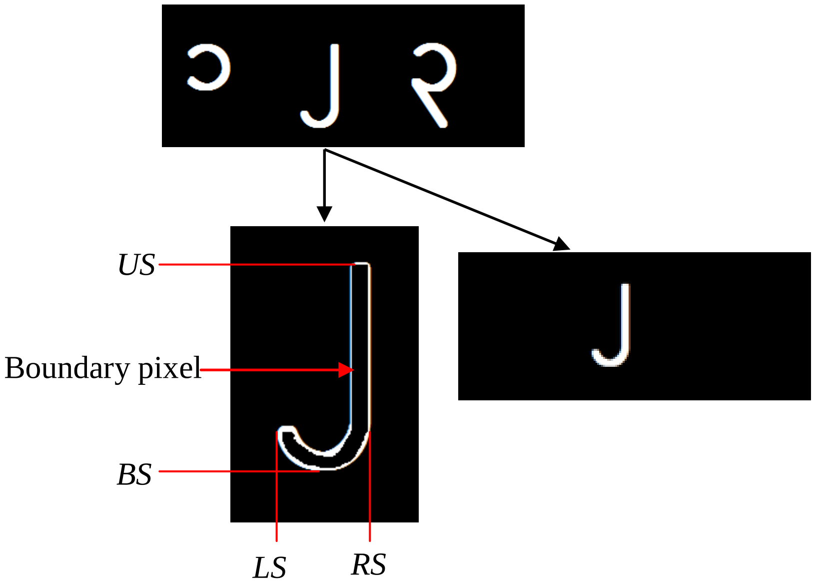


Figure 6-1 Example of character segmentation using boundary tracing method

Finally, the object is extracted and reconstructed in an individual object. In segmenting each character, noise object in the plate are removed by filtering character aspect ratio (width/height). The aspect ratio of Myanmar character of a license plate is not less than 0.45 and not more than 2 because the Myanmar characters are not unique in structure. Some samples are shown in Figure 6-2. Thus slash (/) in the plate is not recognized as a character. The character aspect ratio is given as:

$$AR_c = \frac{W_c}{H_c} = \frac{RS - LS}{US - BS} \tag{6.2}$$

where,

AR_c = Character aspect ratio,

H_c = Character height

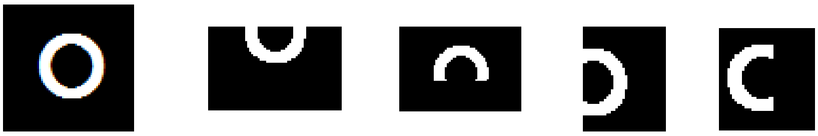
W_c = Character width

Figure 6-2 Aspect ratios of Myanmar characters

6.2 Feature Learning

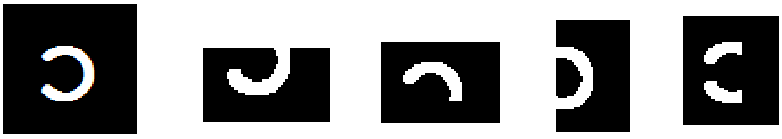
To use feature matching method in character recognition, it is essential to learn distance features of each Myanmar character. However, according to the structures of Myanmar characters, distance features can be learned easily. In this work, a new strategy is proposed to find the distinct features of Myanmar characters; it is featuring learning based on “***Partially cut character structure”***.

Thus, each character is partially cut from *upper, bottom, left and right* sides. In this method, one-third portion is cut from four sides mentioned above. Due to partial cut, the structure of each character becomes very different from others. The detailed procedure can be explained with examples for Myanmar digit zero and one. The partial cut structures of digit zero is shown in Figure 6-3. The partial cut structures of digit one is shown in Figure 6-4. One can see that the features of zero and one are not much different at full structure conditions. When they are partially cut, the different features can be obtained from top cut, bottom cut, left cut and right cut. For example, in right cut of digit one, it becomes two objects but still only one in right cut of digit zero. With these distinct features, it becomes easier to classify the digit. The features extracted for each character is Euler number (P_1), aspect ratio (P_2), ratio of character area to box area (P_3), ratio of perimeter to height of character (P_4), the number of objects after partial cut (P_5). For calculating the Euler number (P_1) of an image, the number of holes with each Myanmar character is shown in Table 6-1.



(a) (b) (c) (d) (e)

Figure 6-3 (a) Full structure of Myanmar digit zero, (b) upper cut, (c) bottom cut, (d) left cut, and (e) right cut



(a) (b) (c) (d) (e)

Figure 6-4 (a) Full structure of Myanmar digit one, (b) upper cut, (c) bottom cut, (d) left cut, and (e) right cut

Here, the parameters are calculated as follows.

$$P_1 = En = 1 - number\ of\ \ holes \tag{6.3}$$

$$P_2 = AR_c = \frac{W_c}{H_c} = \frac{RS - LS}{US - BS} \tag{6.4}$$

$$P_3 = AB_c = \frac{A_c}{W_c \times H_c} \tag{6.5}$$

$$P_4 = PR_c = \frac{P_c}{H_c} \tag{6.6}$$

$$P_5 = n_o \tag{6.7}$$

where,

En = Euler number

AR_c = Character aspect ratio,

AB_c = Character area to box ratio

PR_c = Character perimeter to height ratio

n_o = Number of objects after partially cutting the character

A_c =Total area (number of pixels) of the object

P_c = Perimeter of the object

Table 6-1 Myanmar Characters with the number of holes

Myanmar Character	**Number of Holes**	**Myanmar Character**	**Number of Holes**	**Myanmar Character**	**Number of Holes**
က	0	ဒ	0	၁	0
ခ	1	ဓ	2	၂	0
ဂ	0	န	1	၃	0
ဃ	0	ပ	0	၄	0
င	0	ဖ	1	၅	1
စ	2	ဘ	0	၆	0
ဆ	2	လ	0	၇	0
ဇ	1	သ	0	၈	1
ဈ	2	ဟ	0	၉	0
ည	0	ဠ	0	၀	1
ဏ	1	ယ	0	-	-
ထ	2	အ	1	-	-

Some sample features of Myanmar digit one as shown in Table 6-2. The values of P_1, P_2, P_3, P_4 and P_5 are evaluated by using equations (6.3)-(6.7) for each Myanmar character. First, image of each Myanmar character is created. Then, the required parameters are calculated by using a computer program that includes the equations mentioned above. Here, the values of P_1, P_2, P_3 and P_4 are set as 0 if the number of object (P_5) is more than 1 after the right cut because the features (parameters) should be calculated for only single object.

Table 6-2 Sample Features for Myanmar Digit One

Structure	$\mathbf{P_1}$	$\mathbf{P_2}$	$\mathbf{P_3}$	$\mathbf{P_4}$	$\mathbf{P_5}$
Full character	1	0.962962	4.973148	0.529914	1
Top cut	1	1.529411	4.757294	0.477375	1
Bottom cut	1	1.529411	4.609411	0.468325	1
Left cut	1	0.592592	3.365962	0.557870	1
Right cut	0	0	0	0	2

6.3 Character Recognition

For character recognition, the k-NN classification method is used. The k-NN classification method has been explained in Chapter 5. There are five parameters (features) described above for each condition. There are five conditions (full structure, upper cut, bottom cut, left cut, and right cut) for each character. Thus, there are totally 25 features for each character. The value of k is 1 in k-NN classification. There are totally 34 characters used in Myanmar license plate. After recognizing plate number, the algorithm will produce English characters that are corresponding with Myanmar characters shown in Table 6-3.

Table 6-3 Characters used in Myanmar license plate

Myanmar Character	English Character	Myanmar Character	English Character	Myanmar Character	English Character
က	A	ဒ	M	၁	1
ခ	B	ဓ	N	၂	2
ဂ	C	န	O	၃	3
ဃ	D	ပ	P	၄	4
င	E	ဖ	Q	၅	5
စ	F	ဘ	R	၆	6
ဆ	G	လ	S	၇	7
ဇ	H	သ	T	၈	8
ဈ	I	ဟ	U	၉	9
ည	J	ဋ	V	၀	0
ဏ	K	ယ	W	-	-
ထ	L	အ	X	-	-

CHAPTER 7: SIMULATION RESULTS AND PERFORMANCE EVALUATION

In this chapter, the simulation results and performance evaluation method for the proposed algorithm are explained. The results in the tests using proposed algorithm are presented and discussed to evaluate the performance of the proposed LPR system. Also, the performance of the proposed algorithm is compared with that of some existing algorithms from some previous works.

7.1 Simulation Results

To analyze the reliability (performance) of the proposed system, it is experimentally tested to localize and recognize more than 130 images of Myanmar vehicle license plates. In some images, the car is in the front view position and it is in the back view in some images. Also, some car images which are in skewed position are included in the test. Besides near and far view car images are considered in the performance tests of the algorithm. Thus, the simulation results are logically constructed. The simulation results are included the following details:

7.1.1 Implementation Tool

A graphical user interface (GUI) is created in MATLAB based on the proposed algorithm. The created GUI is shown in Figure 7-1. The figure name (car image) must be inputted and then the button '**Recognize**' must be pressed to see the results. The images redisplayed are the original car image, binary image and binary image of the extracted license plate. The license plate number will be displayed in the box under the '**Plate Number'**.

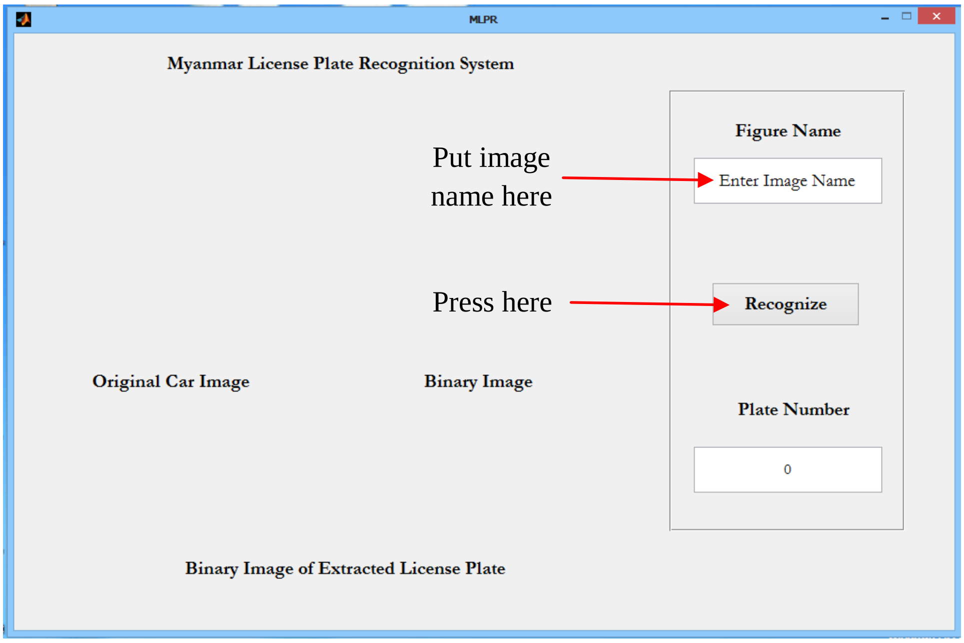


Figure 7-1 GUI based on proposed system

7.1.2 Localizing License Plates with Proposed System

First, the performance of proposed system in localization of the license plate is tested with the car images in which have curved (deformed) and inclined license plates. Also, the plate has the same color (black color) with the car body color. As shown in Figures 7-2, the system correctly locates the deformed and inclined license plates. It proves that the system reduces skewness detection and correction in searching candidate regions.

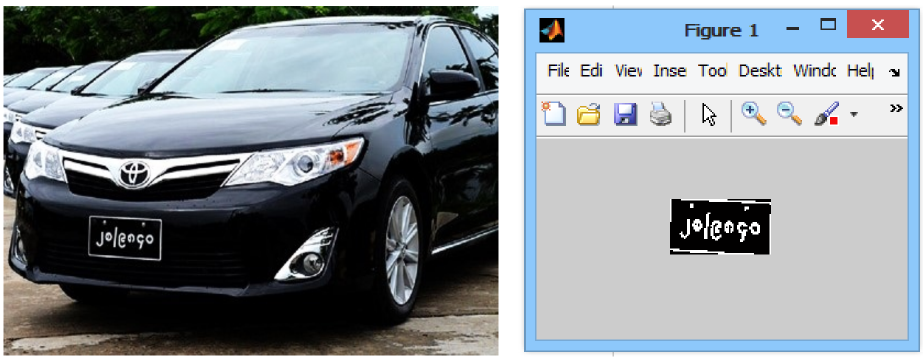


Figure 7-2 Experimental test results for localizing deformed license plate

The other distinct performance of the proposed system is that it can even detect the plate with a wavy edge as shown in Figure 7-3, which is less possible with Hough transform method. In addition, as shown in Figure 7-4 and Figure 7-5, the proposed system is tested for detection license plates under light and in shady region. One can see that the system reliably detect the license plates. Therefore, it verifies that it is less sensitive to lamination effect since the targeted color is black, blue, red and yellow.

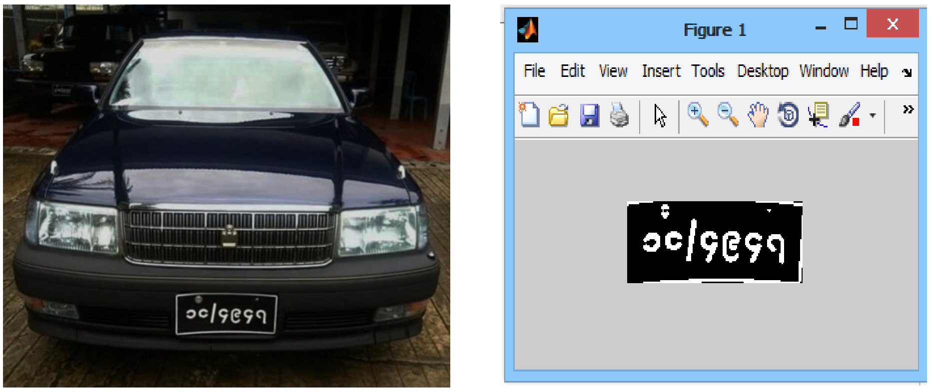


Figure 7-3 Experimental test results for localizing wavy license plate

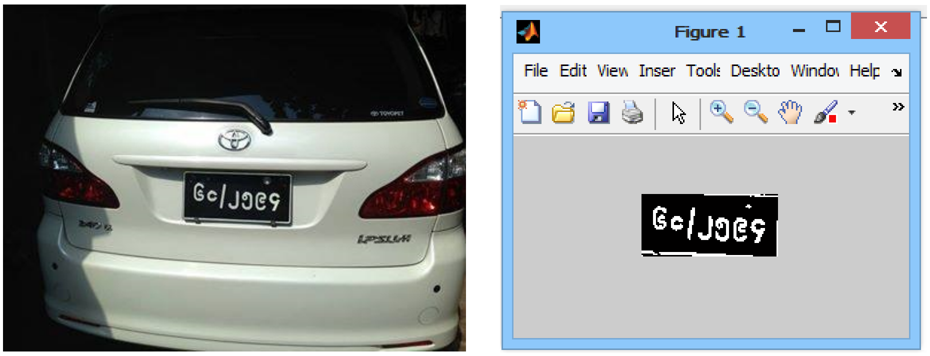


Figure 7-4 Experimental test results for localizing license plate under light

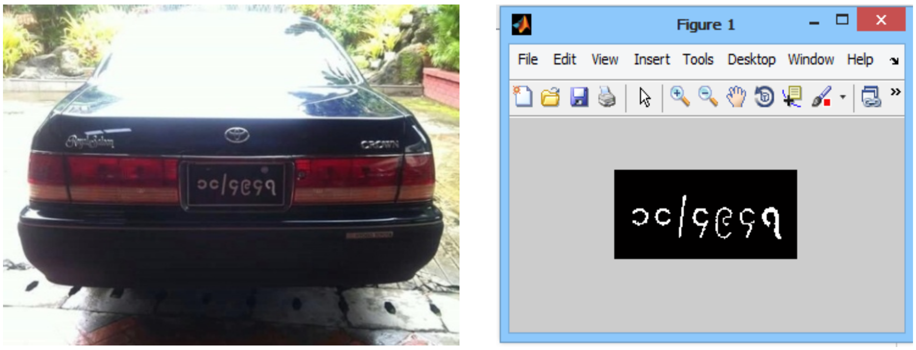


Figure 7-5 Experimental test results for localizing license plate in shady region

Also, the performance of the proposed system is examined for detecting license plates surrounded by similar objects (like-objects). The system is tested with back view car images. In original images, it can be seen that there are many rectangular objects around the license plates. However, the system can exactly localize the license plates. Being different from that in other images, the license plate exists at the lower left corner of the car back cover. The results in Figure 7-6 shows that our proposed system can find the license plate wherever it is.

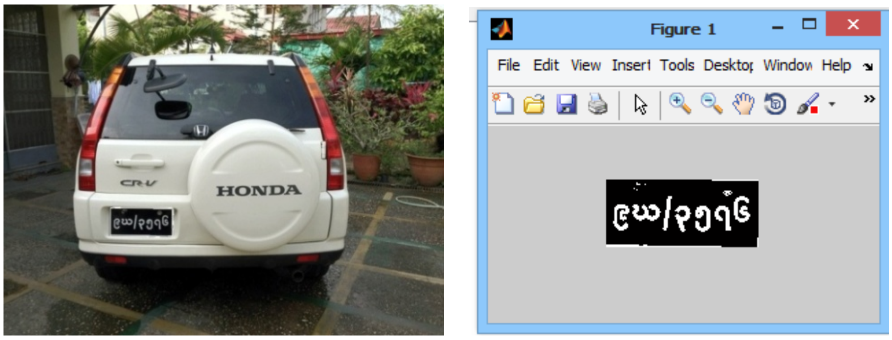


Figure 7-6 Experimental test results for localizing license plate in back view car image

7.1.3 Recognizing Characters with Proposed System

In this section, the performance of the proposed system in recognizing Myanmar characters on license plates is focused. The images with different license plate conditions are tested. First, a car image with a back view is tested. One can see that plate number is correctly recognized in Figure 7-7. Then, the performance of the system is checked by recognizing plate number on a skewed car image. In Figure 7-8, the front view and license plate are a bit skewed. When it is recognized, all the characters on the plate are robustly recognized.

The system is tested with a close up view of the license plate. The plate has a red color. Moreover, the plate is in skewed position. The results depicted in Figure 7-9 proves that the system can still recognize the plate number with 100 % accuracy.

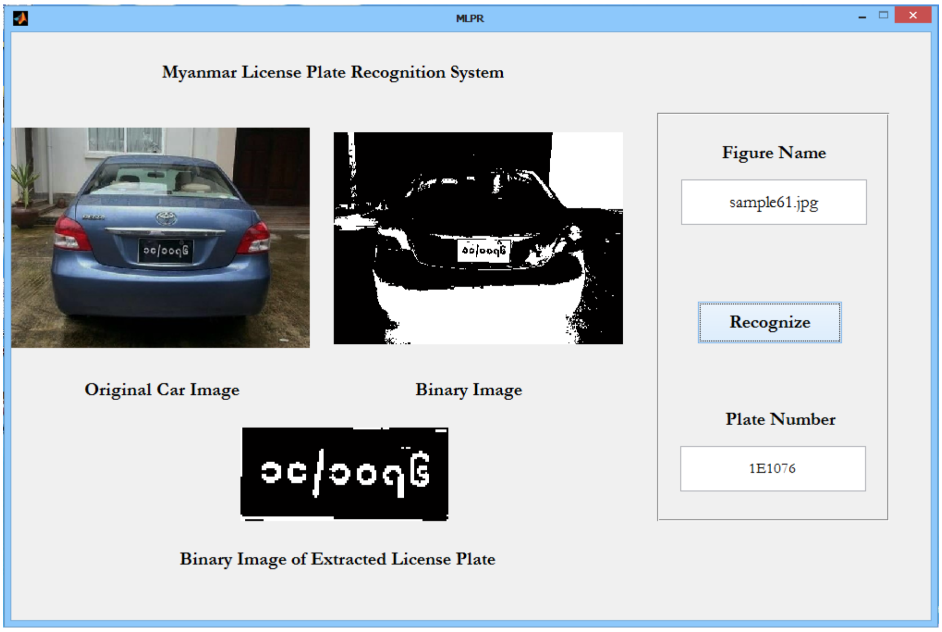


Figure 7-7 Experimental test results for recognizing license plate in back view car image

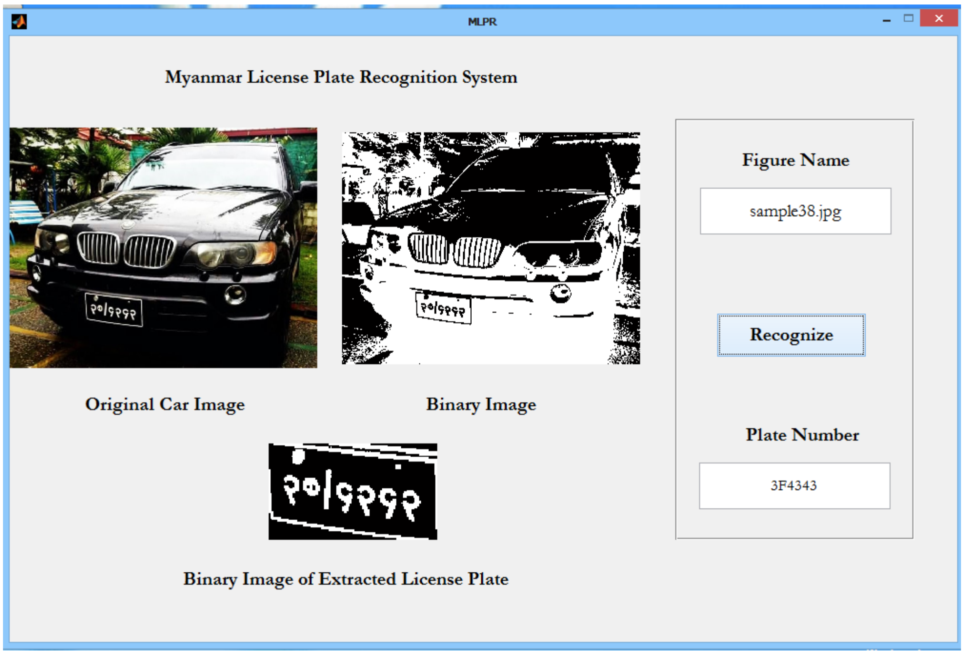


Figure 7-8 Experimental test results for recognizing license plate number in skewed car image

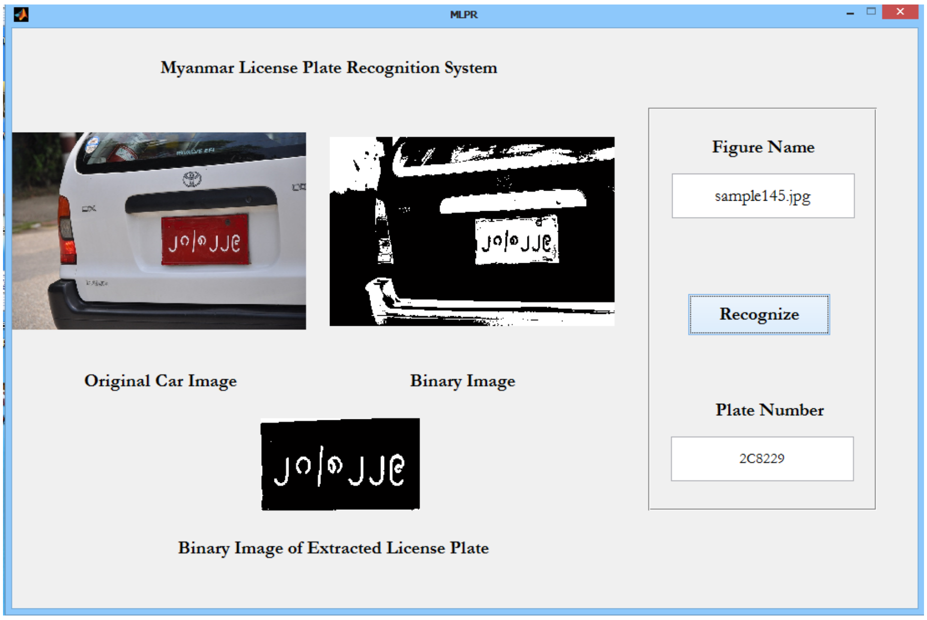


Figure 7-9 Experimental test results for recognizing red color license plate

7.2 Performance Evaluation

In recognizing each car image, the performance of the algorithm is evaluated with different evaluation method as follows.

$$Accuracy(\%) = \frac{NR_{image}}{N_{image}} \times 100 \tag{7-1}$$

where, NR_{image} = Number of recognized image

N_{image} = Total number of input images

Based on the experimental test results of localizing license plates and recognizing characters, the performance of license plate recognition (LPR) system under various image conditions is shown in Table 7-1. Here, totally more than 130 car images are used in the experimental verification of the performance of proposed system. The images are under different conditions such as front, back, far, close, skewed and deformed conditions.

However, it shows very good performance 99.8% in localization, 97.8% in character segmentation and 94.4% in character recognition. The error of 6% is due to very poor resolution and very badly skewed condition of license plate. The main reason is that the plates are adversely skewed and thus, the characters are significantly deformed. No preprocessing and no skew correction are performed in this work. Thus, it is very difficult situation to recognize the characters correctly. It is expected that the performance of the license plate recognition system can be increased up to 100% if the image quality enhancement and skew correction are integrated with the mentioned system.

Table 7-1 Performance of License Plate Recognition (LPR) system under various image conditions

Images in Different Views	**Units of LPR System**		
	Localization of license plate (%)	**Character Segmentation (%)**	**Character Recognition (%)**
Front view	100	100	98.25
Back view	100	96	97.00
Near view	100	100	94.54
Far view	100	99	92.65
Skew (angle) view	99	94	89.87
Total Average	**99.8**	**97.8**	**94.4**

7.2.1 Performance Comparison

The performance of the proposed algorithm is compared with the performances of the other algorithms in previous works [10, 17 and 18]. In the work of Lee et al., [10], HLS color model are used for localizing license plates. Then template matching method is used for recognizing characters. They used 80 sample images.

Then, the authors of [17] applied binary time delay neutral networks (TDNN) for recognition of license plate characters. In their work Zemike moments were used as distinct feature for recognition. They tested the performance of their proposed algorithm with 50 images.

In other algorithms proposed by Yilmaz [18], neural network and image correlation (a hybrid method) is used to recognize the characters. First they recognized the character by using image correction factor. If the correlation factor is less than 0.5, they used neural network. There were totally 50 license plates in their experimental verification of the proposed algorithm.

The comparison is shown in Table 7-1. Here, it can be seen that the proposed algorithm attains a higher performance than the other proposed algorithms. In the previous work, the exact performance for each performance was not mentioned. Thus, only final character recognition rates are compared. The lowest performance is found in TDNN method. It was developed for zoomed characters. It is more difficult to recognize zoomed character than normal condition characters. It could be the main reason for low performance.

The second lowest performance is obtained with neural network and image correlation method. When its performance was measured in terms of number of recognized characters, it is about 96.64%. However, in terms of number of recognized plates, it is only about 80%. It is not favorable because it used two sequence process, image correlation, and neural network. It is very time-consuming due to two processes.

HLS color model [10] gave a comparative performance with the current model. Since the authors [10] used color as a feature to recognize the plate, they have a similar idea with the current algorithm. However, in this proposed algorithm, RGB color model is used. Then, they used template matching method to recognize the characters. For this reason, the recognition performance was high while having a long processing time.

Table 7-2 Performance Comparison

Units of LPR system	**Current work**	**HLS color model** [10]	**TDNN** [17]	**Neural Network and Image Correlation** [18]
Character Recognition Rate	94.4%	91.25%	70%	80%

CHAPTER 8: CONCLUSION

This research is aimed to fulfill the demand of a reliable image processing algorithm in automatic license plate recognition system in Myanmar. In this research, a simple and reliable image processing algorithm for localizing and recognition Myanmar license plates is implemented. The algorithm is based on *Euler number* and *aspect ratio* for candidate region extraction. The *boundary tracing method* is applied for character segmentation and *partially cut character structure* is used for character recognition. The proposed license plate recognition system is tested with more than 130 real filed Myanmar car images and based on these results the following conclusions can be drawn:

- The proposed system can be localized even in skewed and wavy license plates without skewness correction. It is the notable advantage of using Euler number as a filtering parameter.
- Moreover, it locates the license plate even though if the plate color and car body color are the same. It is the advantage of color intensity based binarylization method.
- In character segmentation, no skewness correction is required. Therefore, the proposed system is faster and efficient.

In future, the number plate recognition system can be enhanced with the addition of skew detection and correction algorithms.

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