

RELIABLE LICENSE PLATE RECOGNITION SYSTEM BASED ON ADAPTIVE NON-PLATE FILTRATION METHODS

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ABSTRACT

This paper proposes a technique to filter out the false negative detection of license plate caused by using edge algorithm to specifying the targeting areas. The proposed technique implements filters bases on the histogram value for the three main channels of the image (RGB). The paper consists of the following three main stages: (a) Detection based on edge detecting method, (b) calculating the histogram values of RGB color model, and (c) finally, verifying and detecting valid license plate regions by applying different histogram- based rules on features extracted out from the calculated histogram values. Experimental results show that the proposed method is very effective in assisting to neglect many noises caused by different conditions such as poor illumination and varied weather

Keywords: *license Plate Detection (LPD), Histogram Distribution, Detection Accuracy, False Rejection Rate (FRR)*

1. INTRODUCTION

The accuracy of every detected and recognized identification plate and vehicle in photos taken by surveillance video cameras (SVC) is considered as one of the most crucial factor and has many automated applications depending on it. Such applications include internet of things (IOT), intelligent traffic management (ITS) which include management of toll roads, traffic, crowded areas, speeding and heavy vehicles, and vehicle crimes. One of the major objectives of the SVCs is to capture only the number plates of each and every vehicle as accurately as possible (Hesih et al., 2010). However, this is not the case most of the times as many of false positive nominated blobs caused by using the traditional edge detection method will not be able to be detected using the traditional filtering method, these false positive nominated blobs will be sent as plates to the next stages and will lead to increment in time because of the additional not needed process and decrement in accuracy because of the multiple recognitions caused by detecting both of the non-plate blobs and the real plate (Ming et al, 1996; Jin Chong et al, 2013; Hum et al, 2015).

Most of the current LPR systems and studies consist of the following stages to achieve the target which are as the following as shown in figure 1 (Hum et al, 2014)

- Preprocessing: the aim of this stage is to enhance the image by removing the noise, adjusting the lightening, tilting the skewed frames. After doing these steps the image will be sent to the next stage which is plate extraction.
- Plate Extraction: the aim of this process is to find the plate out of all the surrounding noises and sending it to the next stage which is plate recognition.
- Plate Recognition: the characters will be extracted out of the background and injected to the artificial intelligent classifier to recognize them and convert the image of the plate into text string.
- Fusion: this stage aims to maximize the accuracy of the system by publishing only the highly confident results and suppress the others.

The conducted research will concentrate on the plate extraction stage by improving the filtration of false positive nominated blobs to enhance the overall performance of the LPR. New two

techniques are proposed in order to reach the stated aim. First one is working to differentiate the distribution of the RGB channels for the plate from the non-plate nominated blobs while the other one is concentrating on the splitting the foreground from the background.

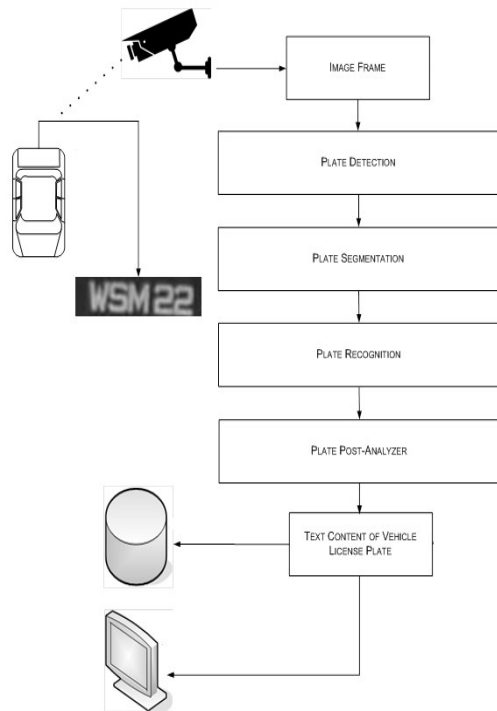


Figure 1: Stages of LPR System (Hum et al., 2015).

2. PROBLEM CONTEXT

Pattern recognition is very easy for us humans. When we look at a license plate our brains can easily recognize the string of letters and numbers it contains, but when it comes to trusting a computer program's pattern recognition and decision making, we will encounter many new problems. In order for us to be able to code a computer program that recognizes and analyzes different strings of texts in images accurately, various combinations of advanced programming algorithms must be used. The basic premise for generic license plate recognition (LPR) system is to have an input image containing a visible license plate of a car. The input image can be acquired from a photo taken with a digital camera or we can get it from a frame of a video. Then, the LPR system must be able to recognize and capture only the area containing the

plate and discard all other irrelevant information, such as the car and the background. If the plate recognition is done successfully, the final output image will be free of noise and other artifacts - and it will only contain the letters and numbers of the license plate. To find the right blob which a plate in LPR system out of all the surrounding noises in the nominated binary image is one of the challenging task (Qin et al, 2016). License plate detection (LPD) is widely used to automate different application related to traffic and vehicle management with least human observation.

Many algorithms are proposed by different researchers using different features to generate the proper binary image which has the plate for the plate detection system. Some of the researchers are using edge statistics (Jin Chong et al, 2013; Hum et al, 2015; Hooi Sin ng, 2015), mathematical morphology methods (Song Qing-kun, 2012), color classification (Vijeta et al, 2016) to find out the plate. While other researchers suggested using Hough transform in order to detect the lines which considered as one of the major features in the plate regions (Hum et al, 2016). Implementing sliding windows as a segmentation technique to extract candidate plate region was also used. Artificial intelligence classifiers such as fuzzy logic, neural network, adaboost and haar features cascade have been also applied in detecting license plates (D. Cui, 2009; Hamam and Azlinah, 2015). In the other hand, some researchers prefer a hybrid detection algorithm, where license plate location method based on characteristics of license shape, character connection and projection was presented (Hooi sin et al, 2015). The main challenges faced in the previous proposed techniques are either they are still limited to some type of noise or they need a lot of processing time which prevent them to be used for real time implementation. The reason behind facing these kind of challenges can be summarized as follows:

One of the main reasons to increase the number of the detected non-plate blobs beside the real plates are the change in color and densities because of many factors such as poor illumination and different weather conditions. As the task of LPR should be real time and all the stages should be executed fast to achieve the needed, many of the researchers proposed to use the edge detection technique to find the plate. Using Sobel edge detection technique to find the target plate will lead to get a huge number of noises along with the detected target plate which will effect on the overall performance of the system (Hum et al., 2015). All of the previous will lead to increase the detected

non-plate blobs which will be sent to the recognition stage for not-needed additional processing and will drop the accuracy and processing time of the whole LPR system (Zhang & Sun, 2011; Khare et al, 2016). The aim of the research is how to find better non-plate filtration techniques that receive the image of conventional Sobel edge detection as an input and able to perform well in removing the false detected plates in different lightening scenarios with a fast time to increase the performance of the whole proposed LPR system.

3. RELATED LITERATURE WORKS

As the main target of the whole conducted research is to find proper filtration technique to remove the non-plate blobs nominated by the thresholding methods. This section tries to find all the works similar to the proposed work in order to conduct a comparison. The comparison will cover the purpose of the work, results, advantages, and disadvantages as the following table:

Table 1: comparison among different researchers in the field noise removal

Author	Title	Purpose	Result	Advantage	Disadvantage
Qin et al. (2016)	Video scene text frames categorization for text detection and recognition	Differentiating the text area from the non-text ones	True positive accuracy was 80.8%	Combine multiscale global and local features	Heavy in computation as it is relying on canny and Sobel thresholding techniques to extract local and global features
Khare et al. (2016)	A quad tree based method for blurred and non-blurred video text frames classification through quality metrics	new method for classifying blurred and non-blurred frames in video	Correct classification for blur and non-blur frames is done with the accuracy of 87.3%	A good preprocessing stage to enhance the overall performance of the plate detection	Too complicated features are used to differentiate the blur from the non-blur frames which is considered not that crucial in the work of LPR
Kaushik, et al. (2015)	Parallelogram and Histogram based Vehicle License Plate Detection	Finding the false positive blobs during the plate detection stage	True positive accuracy was 82.5% on limited dataset (20	A simple histogram of the HSV colour is calculated to find the nominated	The technique is able to find limited type of noises restricted

			plates)	region	to certain condition. Noises like car's brand are not able to be detected
Hum et al. (2015)	Elimination of Signal-resembled Anomalies in Detected Plate	The proposed method amplifies the slight differences between the non-character blobs and the character blobs to enhance the tractability	True positive accuracy was 85.44%	Sift features are calculated among the different blobs to find the distances among them	work assists in finding the noise attached with the plate not to differentiate between the noises and plates
Hoi Sin et al. (2014)	Car plate detection based on conventional edge detection technique	Detecting the car plate using sobel thresholding method	True accuracy of the plate detection was 81.33%	The process is too fast and relying on Sobel thresholding technique	Simple noise detection methods are used based on the geometric features of the blobs as height, width, ratio, and compactness

In addition to the related academic search and comparison, the work tries also to search to list and compare the similarities and differences between the features of the closest prior arts to the proposed work. The aim to do this kind of research is to know the ability of implementing the work in the real life as shown in table 2.

Table 1: similarities with the prior art related to the same work

Prior Art	Similarities	Differences
US 2013 / 0294654 A1	- Both works use the histogram calculation in the license plate recognition system.	- Prior art implements the projection of gray scale histogram to split the character of the plate in the recognition stage. - The propose work uses the conventional edge detection for plate extraction and determines the false positive blob based on conditions applied on the calculated values of

		<p>histogram on RGB channels in addition to rules applied on five different nominated binary images.</p>
<p>US 2013 / 5843794 A1</p>	<p>- Both works use the histogram calculation in the license plate recognition system.</p>	<p>- This invention implements HAAR features to get the plates and determines the false positive blob based on the recognition values of SVM classifier and histogram values of HSV channels</p> <p>- The propose work uses the conventional edge detection for plate extraction and determines the false positive blob based on conditions applied on the calculated values of histogram on RGB channels in addition to rules applied on five different nominated binary images.</p>

One of the main challenges in computer systems is to propose a right research methodology which able to provide a practical implementation and evaluation of the proposed solution. Number of researchers from the field of computer science and from outside had spent a huge efforts to define a proper guidance on how to design science research which can be implemented successfully in engineering, computer science, and information system (Adams et al, 2004). The key points of the guidance are as the following (Chatterjee et al., 2005):

- Disseminate the appropriate reference literature
- Characterize the goals
- Differentiate between the theory and testing research.

Design Science Research Methodology (DSRM) is proposed to be used as an efficient method for technology evaluation (Chatterjee et al., 2005) to achieve the main goal related to evaluate the performance of the proposed LPR system. DSRM method has all the required principles, practices, and procedures in order to perform a well research. The criteria to measure the efficiency of the research are: it is relevant with the conducted literature review, it is a good base to perform the required design research, and it is a good example to show and measure the design search in computer application. The following stages are implemented to complete the research

- Problem Identification and Objective Definition,
- Design and Development
- Demonstration
- Evaluation
- Conclusion

3.1 Problem Identification and Objective Definition

As mentioned in the problem context, Different methods to find false positive nominated areas have been suggested during the last years but improving the techniques that able to be implemented with simple edge detection method in the stage of plate detection in uncontrolled environment is the main goal of this work. Reviewing the previous proposed techniques in enhancing the images, binarizing them, and removing the non-plate regions is done in detail. The main purpose is to find the best and simplest binarization method with a proper and accurate filtering for false positive regions. Fast and accurate

A spider chart is been generated to find the percentage of the similarities between the two works

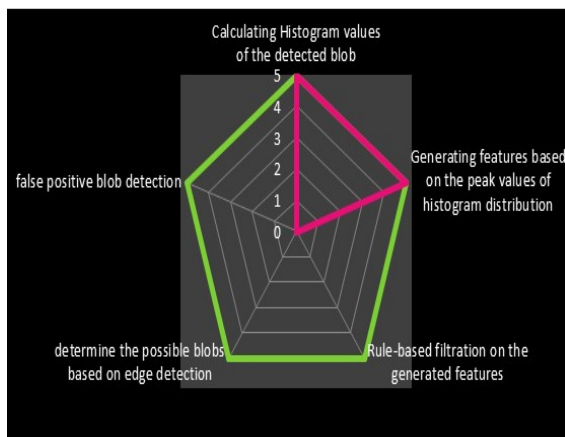


Figure 2: Spider chart for similarity comparison.

4. RESEARCH METHODOLOGY

performing should be defined and fully considered as one of the main critical factors for commercial product. Thus the main contribution can be summarized as the finding a proper non-plate regions detector for simple binarization technique that able to work in an open environment with fast and accurate performance.

3.2 Design and Development

The artifact of the work is a framework for an IT application that performs license plate recognition task. The work will be able to find a proper filtering for non-plate regions on the stage of plate detection to achieve the task in fast time and high accuracy. The steps of the conducted development stage proposed by DSRM can be summarized as the following.

The conventional LPR system consists of three main stages which are: initialization, plate detection, and plate recognition as shown in figure 2.1. As the proposed work mainly applied on the plate level, only LPD will be discussed in both the initialization and the plate detection stages.

In the initialization stage, the image will be grabbed out from the camera stream in order to be processed. As the car plate might appear in some specific region of the scene, there is no point to process the whole image. For the previous reason, a region of interest (ROI) is specified to process the only part of the image falling into the ROI and neglecting the other areas. This stage will assist in speeding up the performance by processing only specific region rather than to process the whole image. The region will be sent to the next stage which is plate detection. The main steps of the plate detection are explained in the figure below:

As the colors are not needed in the task of specifying the plate, grayscale conversion is applied first to shift the image from Red, Green, Blue scale to the gray level. The reason behind the conversion is the fact that plate can be located based on the difference of contrast regardless the color of the image. Using grayscale image will increase the efficiency as RGB image contains three channels which are red, green and blue while grayscale image only contains single channel which reduce the needed computation.

$$\text{Grey} = \frac{R + G + B}{3}$$

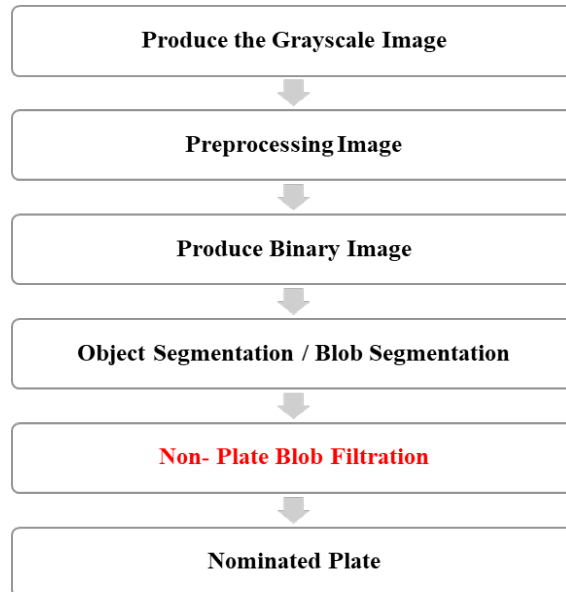


Figure 3: Steps of License Plate Detection.

After converting the image, histogram equalization is performed on the grayscale image to uniform the distribution of intensity level. In another meaning, histogram is a representation of the frequency distributions of the grayscale values from 0 (dark) to 255 (bright). Histogram equalization helps to enhance the image by distributing the intensity levels in evenly. It will help to balance some of the issues that we may face as over-dark, over-bright, low contrast, and high contrast images. This step will assist in giving more enhanced image features for the next steps in the LPR system. The process is explained in the figure below:

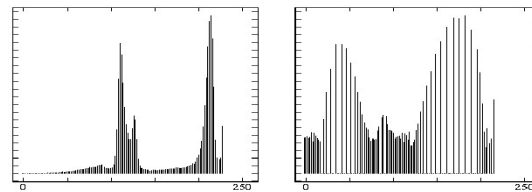


Figure 4: Example of Histogram Equalization.

As the plate considered as a big region in the image itself, smoothing filter, also known as low-pass filter, is proposed to apply as the final step of the pre-processing to get rid of detecting small regions in the image which are definitely not plates after finalizing plate detection. This step is considered a necessary preprocessing step in order to make the plate recognition easier by removing tiny unnecessary details in the image. To implement the smoothing, an average mask

(matrix) will be provided to substitute for the image by using zero padding as below

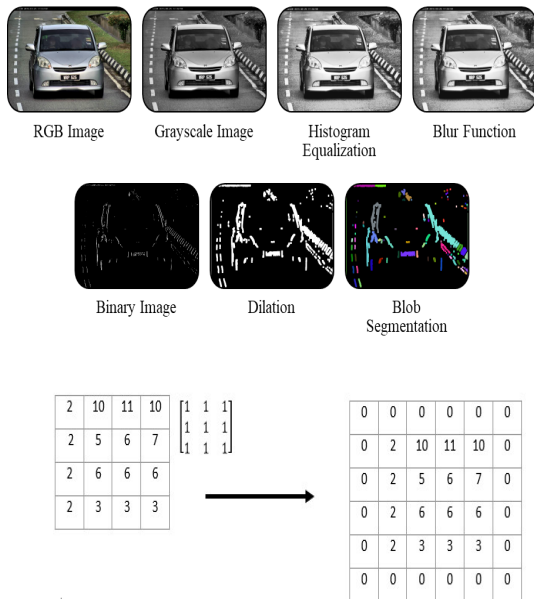


Figure 5: Process of Smoothing the Image

After smoothing out the details, finding plate from the image will be the next task. To achieve that and based on the fact that the plate consists of two highly different colors in contrast such as black and white, red and white, or green and black. Simple edge detection method following Sobel concept will be applied to binarize the image as the following. Difference between the left and the right edges of each pixel will be calculated and compared to the threshold value. In case the calculated value exceeds the assigned threshold value, pixel will be assigned as foreground or it will be assigned to the background of the image. This means, thresholding will turn each pixel of the image to either black (value of 0) or white (value of 255) depending on the calculation of the values. Right after performing edge detection, dilation algorithm will be applied to the image for the purpose to close any gap in the detected binary edges. By applying dilation the algorithm enlarges the boundaries of the pixels of relevant information resulting in expanding the structures of the image. When the boundaries of the shapes are enlarged, small holes inside the shapes become smaller or even disappear from the image. Dilation works by checking the surrounding pixels of every single pixel, and if any of the surrounding pixels has the value of 255, the middle pixel's value will also be changed into 255. If the middle pixel's value is 255,

but none of the surrounding pixels have the value of 255, the middle pixel's value will be changed into 0.

To get the connected regions as individual nominated blobs out of the binary image, connected component labeling method is applied to isolate the connected areas into separated regions (blobs). The technique will be applied by checking the upper and the left pixels of the target pixel to assign label to them. After assigning the labels to the pixel, labeling correction is done by scanning the pixels again to avoid getting two or more labels in the same region. All the pixels which have same label will be considered as one blob and will be sent to the next stage to know whether it is a real plate or not. All the previous mentioned stages to get nominated blobs out of the whole image will be shown in a real scenario as below:

Figure 6: Steps Required to Get the Nominated Blobs for Plate Recognition.

After getting the nominated blobs to be plates, a very simple filtration method can be applied to remove some of the clear non-plate blobs. These techniques are based on the geometric features as the size of the blob, orientation, width to height value, white pixels density. The output of applying these simple filtration methods on the whole nominated blobs will be as below

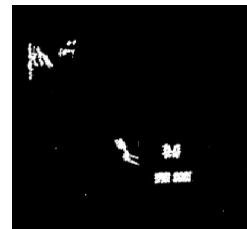


Figure 7: Remaining Nominated Blobs after Applying Basic Filtration Methods

For the remaining stubborn noise, two different non-plate filtration methods are applied on two different levels. The first one is applied on the

RGB level called RGB histogram-based rules which rely on the simple edge detection method to locate the nominated areas. After locating the areas, RGB histogram-based stage is applied to remove as much noise as we can. The Second stage called OTSU-based stage is based on filtering the remaining blob by proposing an adaptive OTSU thresholding technique. Both of the proposed techniques are going to be discussed in detail in the following section.

3.2.1 Rule-based histogram filtration stage

As we can notice from the figure 6, multiple blobs are nominated to be plates as they are overriding the filtering conditions and having properties similar to the plates (compactness, size, ratio, etc), unfortunately all of them are inaccurate plates but one. For that reason another filtration method should be proposed in different level to be able to filter them. As the plated will be in color mode which has three known channels called red, green, and blue, method relying on the distribution of the different channels has been suggested. By calculating the distribution of the different colors channels, dedicated condition had been proposed to be applied in the purpose to filter out noise from the real plate in the LPR system as clarified below.

By using Histogram values for all three RGB channels, we analyze that specific conditions might be applied to filter out noise based on studying the intensity distribution of Histogram values for license plate available in our database. This is illustrated in figure 7.

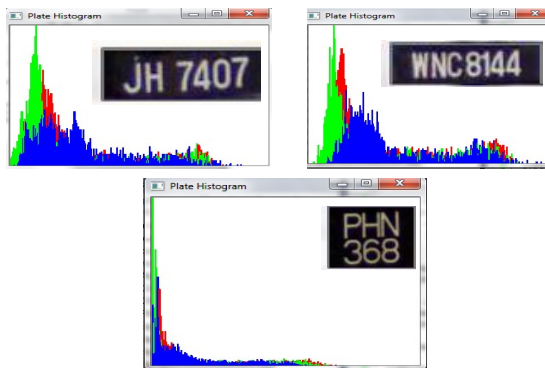


Figure 8: RGB Histogram Distributions for Car Plates.

Histogram distribution for each channel is divided into five ranges $S1[0,50]$, $S2[50,100]$, $S3[100,150]$, $S4[150,200]$, and $S5[200, 255]$. Following values are calculated for each channel to be used later in the filtration process:

- (PeakR_i , PeakG_i, PeakB_i) Number of peaks values that exceed 100 for each range.
- (IndR_i, IndG_i, IndB_i) Index of max value for each range.
- (MaxIndR, MaxIndG, MaxIndB) Index of max value among all the ranges.

Where $i \in [1, 5]$

Different filters are applied using the distribution of the RGB channels (Lama and Babak, 2017)

Rule1: Non Standard color detector based on color variance $MaxDiff > 70$

Where

$$MaxDiff = \text{abs}(MaxIndR - MaxIndG)$$

Rule2: Multi-colors detector based on extreme color

$$((SumPR > 15) \ \&\& \ (SumPG > 15) \ \&\& \ (SumPB > 15))$$

&&

$$((PeakR3 > 2) \ || \ (PeakG3 > 2) \ || \ (PeakB3 > 2))$$

Where

$$SumPR = PeakR1 + PeakR2 + PeakR3 + PeakR4 + PeakR5$$

$$SumPG = PeakG1 + PeakG2 + PeakG3 + PeakG4 + PeakG5$$

$$SumPB = PeakB1 + PeakB2 + PeakB3 + PeakB4 + PeakB5$$

Rule3: Beams detector based on dominant color

$$(MaxIndR > 200 \ \&\& \ MaxIndR < 235 \ \&\& \ PeakR1 == 0 \ \&\& \ PeakR2 == 0)$$

OR

$$(MaxIndG > 200 \ \&\& \ MaxIndG < 235 \ \&\& \ PeakG1 == 0 \ \&\& \ PeakG2 == 0)$$

OR

$$(MaxIndB > 200 \ \&\& \ MaxIndB < 235 \ \&\& \ PeakB1 == 0 \ \&\& \ PeakB2 == 0)$$

The effectiveness of the proposed filter is clarified in the below figure as samples of detected noise are shown for each one of the three invented rules.

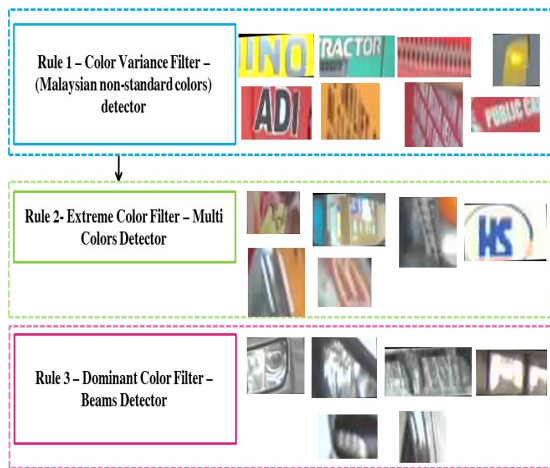


Figure 9. Samples of Detected Blobs for Each Rule in the Rule-Based Histogram Filtration

3.2.2 OTSU-based stage

As the generated binary image of the Malaysian plate has some unique characteristics. These characteristics might be used in a way to differentiate the real plate from the non-plate blobs which pass the histogram-based and the initial basic filtration rules. The unique features are based on the relation among the contents of the blob itself which called sub blobs. In more details, the sub blobs of the plate which are the characters and the digits have common feature as similar height, similar with, standard gaps. By designing some rules and weights based on these relation, a proper filtration method can be achieved and the nominated clear binary image will be send for the next character recognition stage. The main challenge of the proposed filter is to find the best thresholding method that able to separate the foreground from the background and provide a clear binary image with proper relation among the sub blobs. As the source of the binary image is the gray image, a right calculation of the gray scale value is very important due to the fact that the images are captured in adverse conditions with different lightening. These factors might lead to make process of isolating the characters which are the foreground from the background as a challenging process. For that reason, a wrong estimation of the gray values might lead to binary plate image without clear and correct relation between the sub blobs which lead to wrong filtration in addition to wrong recognition. To avoid that, background based calculation (BBC) step is applied on each individual input nominated blob from the histogram-based filtration stage as the following:

BBC will find the mean and std value of the gray scaled input blob to be used for grayscale calculation based on different scaling values. Different scaling values for each mean and standard deviation in the applied equation will help to generate five nominated grayscale images. The generation is based on the idea of assigning a different scale to the variance before adding it to the mean. The scale ranges from -0.5, -0.25, 0, 0.6, 0.8 and the values used to generate the different grayscale images are as the following:

$$iVal1 = \mu + 0.8 * \sigma_f^2$$

$$iVal2 = \mu + 0.6 * \sigma_f^2$$

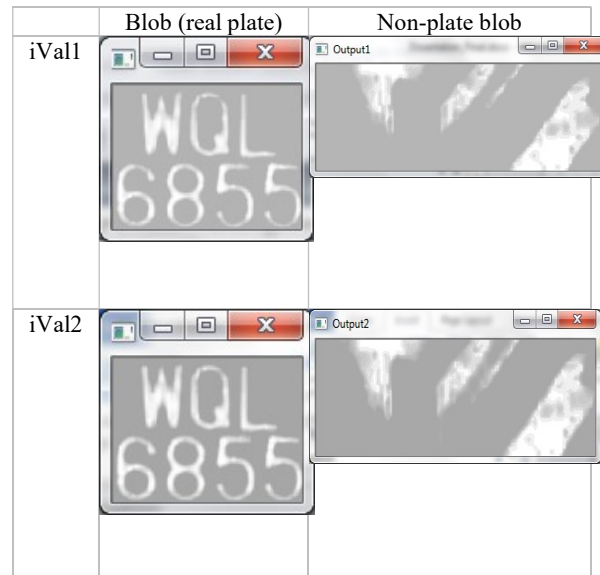
$$iVal3 = \mu$$

$$iVal4 = \mu - 0.5 * \sigma_f^2$$

$$iVal5 = \mu - 0.25 * \sigma_f^2$$

μ is a mean, (σ^2) Variance

To generate the new output gray image for each value the following condition will be used for grayscale generation
If image pixel value < iVal_i then image pixel value
iVal_i = else no change



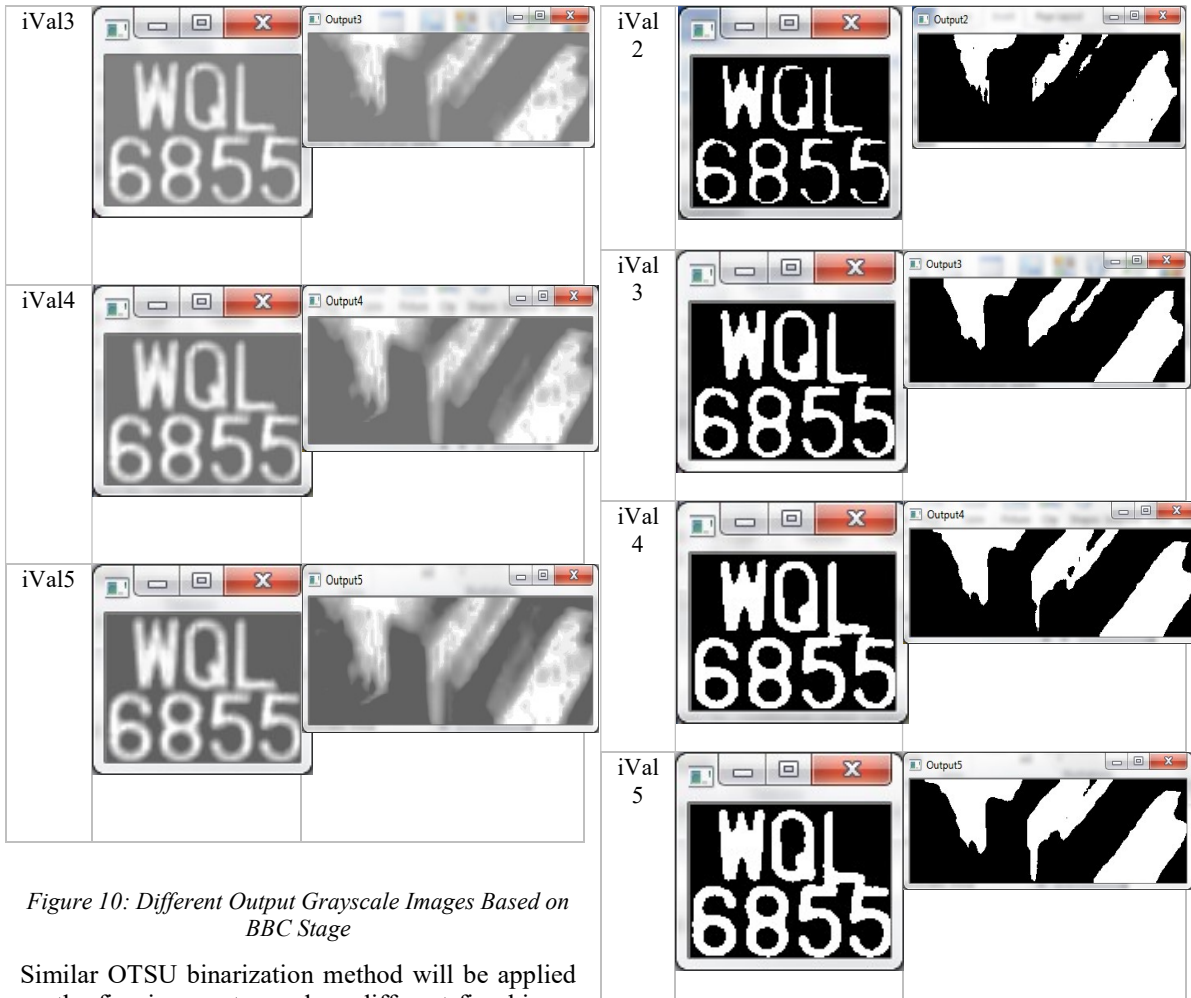
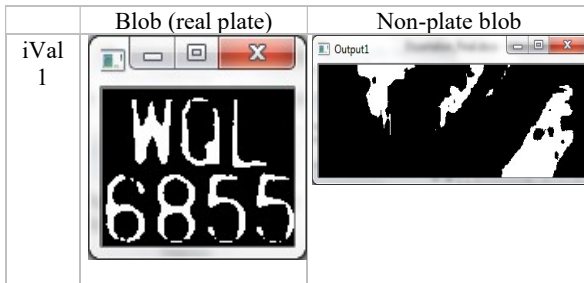


Figure 10: Different Output Grayscale Images Based on BBC Stage

Similar OTSU binarization method will be applied on the five images to produce different five binary images. Otsu method is a global common thresholding technique calculates the value which maximize the inter variance among the two different classes. The five output binary images for both plate and noise are shown in the figure below

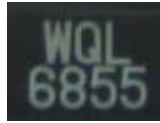
Figure 11: Different Output Binary Images Based on GT Stage

The most important part after getting the binary image is to find a way to assign weights based on the relation among the different sub blobs for each binary image. The best binary image based on the highest weight values will be chosen among the five nominees. The weight value of this blob will be compared with a threshold value to decide whether it is plate and should be sent to the recognition stage or not. Before proceeding to the weight calculation, the type of the blob should be specified whether it is single blob (one line) or double blob two lines. The reason behind specifying the type of the blob is that different rules are designed for different





Single blob



double blob

Figure 12: Types of the Blobs

Specific rule for single blob is as the following:


- If the height of all the sub blobs are more than 80% of the height of the blob itself, the weight will be increased by one
- If the width of each sub blob is equal or less by five from the total width of the blob divided by the total number of sub blobs, the weight will be increased by one





Specific rule for double blob is as the following:

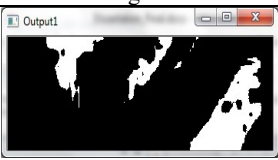


- If the height of all the sub blobs are more than 30% and less than 60% of the height of the blob itself, the weight will be increased by one
- If the width of each upper part sub blob is equal or less by five from the total width of the blob divided by the total number of upper sub blobs, the weight will be increased by one.

Rules common between single and double blobs

- If the gaps between each consequent two sub blobs are equal or less by five from the average of all the gaps, the weight will be increased by one.
- If the total white density of whole sub blobs is more than 60% of the area of the whole blob, the weight will be increased by one.

	Double Blob	Weights Calculation
iVal1		+1

iVal2		+2
iVal3		+4 (Chosen Blbo)
iVal4		+1
iVal5		+1

	Single Blob	Weights
iVal1		0
iVal2		0
iVal3		0

iVal4		+2 (Chosen Blob)
iVal5		+2

Figure 13: Evaluation and Weights Calculation

The best calculated weights will be compared with a threshold value which is 3 in our case to decide whether to proceed for the next stages or not.



iVal3		+4 (chosen Blob) will be sent to the next stage
iVal4		+2 (chosen blob) will be removed as noise

Figure 14: Evaluation and Filtration Stage

3.3 Demonstration

Testing will be carried using the plates gathered in the data collection stage, once the artifact is completed. The data will be implemented to it and the accuracy will be calculated. The suggested thresholding and rules values will be tuned based on experiment till reaching to the satisfied accuracy level. To verify that the proposed method is a good method, comparison and evaluation with other methods suggested by other researchers will be done before finalizing the values and the proposed techniques

3.4 Evaluation

This stage consists of discussing the results of the proposed technique to evaluate whether the target objectives are achieved successfully or not.

5. EXPERIMENTATION AND ANALYSIS

All the works related to propose the non-plate filtration techniques and the stages of the LPR system needed to be used are covered in the previous chapters. In the current chapter, the aim to prove that the proposed system is accurate and fast which replied the last two research questions is going to be conducted here. The main purpose of this part is to prove achieving the stated goals by evaluating the performance of LPR using testing and experimental methods. The experimental tests are done to calculate over the proposed system to prove the following:

- Accuracy of the developed two non-plate blob filtration techniques
- Ability to use the proposed LPR system as a commercialized system.

4.1 Experimental Tools

This section emphasis on how the data had been collected by the researcher to be used in the experiments of the proposed LPR system. Gathering a proper data is one of the crucial conditions to get correct deliverables out of the proposed research. On the other hand, nominating the correct calculation metric to measure the performance of the research is very important. To achieve the previous, evaluation criteria should be dedicated carefully to be able to measure the level of achieving the objectives.

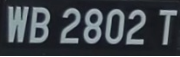


4.1.1 Data collection

Collecting a general dataset that includes all possible situations is of great importance for providing a valid and honest assessment and to identify any problems or issues in the program. The gathered data attempts to represent different characteristics of the plates such as color (taxi, and normal car), shape (double and single plates), and lightening in open environment to obtain a variety of challenging noises. Out of many factors that could be used to evaluate the quality of the gathered dataset,

Table 3: Gathered Database as an Output of the Observation Method

Total images (plates)	One row license plate (rectangle plate)	Two lines license plate (square shape)	Reversed color plate (Taxi plate)
522	350	100	72

Table 4: Sample of Different Existed Plates in Malaysia

Single Line/Car	Double format/Car	Taxi plates
		

4.1.2 Evaluation criteria

The evaluation criteria will be using the benchmarking concept which is based on comparing the performance of the solution with other proposed solutions. Benchmarking is going to be applied into two levels; the first level is relying on evaluating the performance of the proposed non-plate filtration methods which is called engine evaluation. The second evaluation is related on evaluating the performance of the whole LPR system with other proposed commercial LPR solutions. This kind of benchmarking called system evaluation. To test the performance, true positive, false positive and false negative factors are calculated to measure the overall accuracy of the LPD system. True positive means the number of noise detected as noises while false negative is the plate detected as noise. At the end, the false negative refers to the missed plates as the plate kicked as noise. The overall accuracy of the LPD system can be calculated as the following:

- Accuracy of filtration (Precision) = (true positive – false negative) / (total number of noises)
- For the benchmarking stage, the full LPR performance is compared based on calculating the following metrics:
- LPR True Positive: refer to the number of the plate recognized correctly
- LPR False Negative: refer to the number of the plate which are missed as they are detected as noises
- LPR True negative: refer to the number of the noises which recognized as plates.
- LPR Precision = LPP True Positive / total number of plates

4.2 Accuracy of Rule-Based Histogram Filtration

The accuracy of the three proposed filtration rules based on the distribution of the RGB channels is calculated based on the data collected as mentioned. The three proposed filters are as the following:

- Filter1: Non Standard color detector based on color variance.
- Filter2: Multi-colors detector based on extreme color.
- Filter3: Beams detector based on dominant color.

The distribution of the RGB channels for the real plates collected in the databased looks as the following:

The testing is applied on a video which contains 522 cars captured during daylight as shown in the figure below. The resolution of the frame is 800 times 600. The over noise kicked by the three histogram filtration rules is shown in the table below tacking into consideration that the total number of noise caused by the edge detection over the whole video is 2445 blobs and the total number of the real plates is 522

Table 5: Results of Histogram-Based Filtration

Filter	True Positive	False negative
Filter 1	117	2
Filter 2	154	1
Filter 3	989	12

Based on the proposed evaluation model proposed, Accuracy is calculated for these filters and the overall proposed technique as the following:

Table 6: Accuracy of Histogram-Based Filtration

Filter	Accuracy of filtration
Filter 1	4.7% (117-2)/2445
Filter 2	6.2% (154-1)/2445
Filter 3	39.9% (989-12)/2445
Rule-Based Histogram Method	50.9% (1260-15)/2445

4.3 Accuracy of OTSU-Based Filtration

This technique is based on applying rules on the five nominated OTSU binary images to calculate the weights and differentiate the noise out of the plate. The accuracy is calculated for each

category for each nominated grayscale out of the five nominated images. The final accuracy of the proposed OTSU-based stage is calculated based on applying the rule to get the best grayscale image out of the five images and make the decision. The detected noise remained after applying the rule-based histogram filtration stage is $2445 - 1260 = 1185$. These noises are classified into double and single noises relying on calculating the ratio between the height and the width.

Table 7: Classifying the Plate and Noise into Double and Single

	Single	Double
Noise	739 out of 1185	446 out of 1185
Plate	$345 + 43 = 393$	$90 + 29 = 129$

By applying OTSU-Based method on each nominated grayscale for each single and double plate, the calculations of the true positive and the false negative for single blobs are as the following:

Table 8: True Positive and False Negative for Single Blobs using OTSU-Based Filtration

	Score 1	Score 2	Score 3	Score 4	Score 5
True Positive	510	488	422	465	498
False Negative	10	7	4	5	11

Table 9: True positive and false negative for double blobs using OTSU-based filtration

	Score 1	Score 2	Score 3	Score 4	Score 5
True Positive	376	324	298	322	353
False Negative	7	4	3	7	8

The calculation of the accuracy for filtration for both single and double noises will be as the following

Table 10: The Filtration Accuracy for Detected Noises by Edge Detection

	Score 1	Score 2	Score 3	Score 4	Score 5
Single	67.5% (510-)	65.08%	57.2%	62.24%	65.89%

Noise	10)/739	(488-7)/739	(427-4)/739	(465-5)/739	(498-11)/739
Double Noise	69.2% (316-7)/446	58.2% (264-4)/446	50.4% (228-3)/446	57.1% (262-7)/446	63.9% (293-8)/446

As the proposed method is based on nominating the best score to be sent for the decision making level, the calculation of the filtration accuracy for both single and double blobs are done again to find the accuracy of the proposed OTSU-based stage as the following:

Table 11: Accuracy of OTSU-Based Method

	Nominated Score
Single Noise	61.5% (457-2)/739
Double noise	59.8% (268-1)/446

6. CONCLUSION

The main aim of the research is to achieve the goal stated at the begging which is related to enhance the performance of the LPR system by enhancing the filtration on the detection stage based on conventional edge detection method. To achieve the enhancement on the engine level and the whole system level two stages are done which are

- Proposing a filtration rules that works in different environments and illumination with the ability to remove as much as possible noises without removing the real plate
- Providing a reliable LPR solution which can be used in the real time application with good accuracy and performance.

At the end of the research, the two achievements of the research are as the following:

- Propose a filtration method based on RGB histogram which able to remove three types of different noises called:
 - Non-standard colour detector based on colour variance
 - Multi-colours detector based on extreme colour
 - Beams detector based on dominant colour

This stage is applied on the RGB image and able to filter different type of noises. On the other hand, another method based on proposing OTSU-rule is done. The method is based on generating different grayscale images to tackle illumination issues. Then the images will be binarized using OTSU techniques. At the end, a designed rules are applied to score the blob and decide with the blob is a noise or not.

- The second achievement is related to propose a practical LPR system that can be used in real life application with high accuracy.

7. SUMMARY

The Final proposed system is based on applying the rule-based histogram method as the first stage then the output will be applied on the OTSU-based stage to finalize the plated detection method. The nominated blobs out of the detection stage will be sent to the next plate recognition stage.

The proposed two methods are able to remove 88.44% of the total noise created by using traditional edge detection method. This enhancement will add a great value to the LPR system by decreasing the error rate caused by recognizing two results one is related to the correct plate and the other related to the results of noise which is detected as real plate. The previous type of error in LPR system called as double recognition error. On the other hand, the proposed two filtration methods is adding a great value to the processing time by removing a lot of noises on the detection stage and save the waste time needed to process them in the recognition stage.

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