The use of mathematical morphology and template matching in automatic malaysian car plate number recognition

S A Halim¹, M S Zulkifli¹ and M A Zulkipli¹

¹Centre of Mathematical Study, Faculty of Computer and Mathematical Sciences, UniversitiTeknologi MARA, 40450 Shah Alam, Selangor DarulEhsan

suhaila@tmsk.uitm.edu.my

Abstract. Car plate number nowadays is an essential component to be recognized because of the useful of its widely application especially in this technological era. Therefore, a method of detection, extraction and recognition of car plate image are important in order to be applied in various applications. Presently, the existing methods have several problems that lead to this study which are high time consuming for training purposes and requirement of complex steps in preparing the whole car plate recognition process. Therefore, the following objectives are set up that are to implement recognition method using Mathematical Morphology and Template Matching on car image which contain plate number. Next, is to evaluate the accuracy of the method. In implementing this study, 25 images data of car with its plate number are collected and used. Mathematical Morphology is used to detect the edge of each character on the car plate while the Template Matching as a tool to match up the detected and template character in order to recognize the registered car plate number. The accuracy of the method is evaluated using percentage recognition rate. Results show that the performance of the method successfully extracted the car plate number area by 92% of the original image. Then for the other of 23 extracted images, it was 86.95% that successfully recognized the number plate. All of these results create its own novelties which are the ability to reduce processing time and having high detection and recognition rate. In conclusion, the proposed method can be one of the alternatives in car plate recognition process in the meanwhile it can be used widely in digital data transfer such as Automatic Enforcement System (AES), automatic saved car park number in smart parking system and high technological verification application of home security system.

1. Introduction
As in present, car plate detection can be seen as a crucial part which helps human in identifying the car plate character in the fastest way which can saves energy and time. Human recorded car plate number manually until the starter of the boundless technology in photo-enforcement industry as before the existing of the computer-based car plate recognition. This situation grows rapidly in the unlimited range of applications since the car plate of vehicles is the most primary, human understandable and mandatory identifier of motor vehicles. This system declared as traffic law enforcement rules and it is extensively applied over the world to identify the car that break any law or make any kind of crime. Besides, there are other useful applications such as vehicle access control, speed trap, Automated
Enforcement System (AES), automatic toll collection, real-time monitoring and parking area security and management. In the application of car plate recognition, image processing is the major process concerned in order to detect an image. Image processing is a technique to develop actual image in the digital form by extracting some useful information from it. Similarly in car plate detection, the information of registered number and character on each of car plate is very important to various applications in the real life especially for Road Transportation Department (JPJ) or for a job scope in Ministry of Transportation.

The recognition system of car plate is still a very challenging problem as the format of plate itself is different and varies and the image acquisition condition. Besides that, the disadvantages of the current a methods also become the main problems in car plate recognition system. In edge detection process, the current method using Canny method could produce unclean image because of the high amount of broken detail with complex texture and noise.

For recognition process, artificial neural network (ANN) and support vector machine (SVM) contribute to long time taken and composite method in preparing the whole process. Moreover, by using these two methods, it requires more training process on method preparation. Therefore, Mathematical Morphology and Template Matching are being implemented in this study as it is a flexible and straightforward method to use as compare with neural network that required training process. The objectives are setup as to propose and implement recognition method using Mathematical Morphology and Template Matching for car plate number in digital form and to evaluate the performance in term of accuracy. Furthermore, this study focused on standard Malaysia car plate for standardizing and controlling data purposes.

2. Literature Review

Edge detection discusses the process of searching the boundaries exist in the image and pointedly cleans out useless information by dropping the amount of data [1]. Recently, there are lot of methods used in image edge detection introduced by many popular scholars such as Sobel, Canny and Mathematical Morphology. Sobel edge detection is an edge indicator using two masks with 3x3 sizes which are approximating the gradient in the $x$-direction and $y$-direction. Zaman, Rahman, Jumaat and Yasiran [2] applied canny edge detector as feature extraction method on existing MIAS mini Mammographic database.

Mathematical Morphology has two main basic operations which are erosion and dilation. Mathematical Morphology can be used to process certain types of noise in images, but can also be used more generally in filtering, segmentation, classification, analysis and coding of visual-type data. Combination of Canny edge detection and Mathematical Morphology of dilation and erosion was used as feature extraction of Paddy disease to be fed into recognition system [3,4]. Mathematical Morphology has strong anti-noise capability and real time to maintaining the basic form of image features. Furthermore, it also wide range of applications such as noise removal, image segmentation, edge detection, feature extraction, texture analysis, image restoration and reconstruction, image compression and other image processing fields. Due to the advantages of Mathematical Morphology compared to the other existing method in detecting edge of car plate character, hence this method is used in this study to find the edge of each character before the computer recognize each of it.

In recognition phase, ANN methods have disadvantages that make this study prefer to use Template Matching rather than ANN method. From the research done by Jodas, Marranghello, Perieira and Guido[5], they found that ANN method shows that it needs a tone of command in preparing the method that make it complicated and difficult to implement. Furthermore, ANN method also spent a lot of time to get process especially during the training phase which includes supervised and unsupervised training [6]. Supervised training implicates appliance of providing the network while unsupervised training is where the network has to make logic of the input without outside aids [7]. Yusoff, Rahman, Mutalib and Mohamed[8] investigated the selection of radius, size of map, learning rate and epoch number in neural network learning for licence plate identification.
Phangtriastu, Harefa and Tanoto[9], stated that there are a lot of kernel’s type which are famous to practice with SVM for examples Linear Kernel, Gaussian Kernel and Polynomial Kernel. SVM required a difficult method that can lead to confusion for user. SVM has a bad attitude where it clarified the data without knowing the exact distribution. Thus it shows that SVM is easily manipulating any kind of data including the unrelated one. Furthermore, Goyal and Bhatia [10] stated that there are also a method used that cannot predict the existing of spacing and syntax rule that affect the car plate character detection such as by using SVM.

In the other hand, Template Matching is one of the famous ways to recognize the character on the car plate. Sharma [11] proposed technique for vehicle number plate recognition on Nepali number plates using normalize correlation and phase correlation of template matching. According to Gilly and Raimond[12], Template Matching is a method that equates portions of image against one another. After the image has been extracted, process of Template Matching segmenting all the character detected on the car plate then it matching up the images of license plate with the template created. The template in database acts as a benchmark data or prototype to be compared in order to calculate the correlation value [13]. The Template Matching takes a place by matching up the extracted individual character with the standard character in the templates using correlation function. The character with the maximum value of correlation function matched with the template is considered[14].

3. Methodology
There are four significant steps as shown in Figure 1 that involved in recognizing each character of the car plate using Mathematical Morphology and Template Matching.

| Method for Car Plate Recognition |
|----------------------------------|
| Step 1: Data Collection           |
| Step 2: Process of Detection and Extraction |
| Step 3: Process of Recognition using Template Matching |
| Step 4: Performance Evaluation using percentage recognition rate |

Figure 1. Four Steps in Car Plate Recognition Method.

In step 1, a set of car with plate number images are collected within a fixed distance using Huawei Nova 2i phone with 16MP camera in outdoor environment.

Grayscale image is an image in a range of shades of grey known in pixel of [0, 255] without apparent color [15]. Then, the grayscale image is converted to binary image using thresholding. Thresholding is replacing all pixels in the input image with luminance greater than level with the value 1 (white) and replacing all other pixels with the value 0 (black).

Next, step 2 is the detection and extraction process. The part of the car plate image was extracted from the whole image by selecting the maximum white area of the binary image. Mathematical Morphology method is used to detect and adjust the edges of each character to ensure the characters are clearly detect and easy to recognize. Mathematical Morphology of dilation and erosion are applied in this study.

In recognition process of step 3, Template Matching is involved. The matching process is done on a pixel by pixel basis in which the numerical index of each pixel is calculated. Template Matching acts as a tool to recognize the detected characters with the template of Malaysia standard car plate character by using the highest value of correlation.

Finally, in step 4, the performance of the method has been evaluated using percentage recognition rate (%RR) for the success rate of car plate detection and character recognition in order to justify the efficiency of the whole process.

\[
\% RR = \frac{TP}{n} \times 100\% 
\]
where the $TP$ is true positive in which the image is correctly detected, $n$ is the number of data.

In this study, the method is tested with 25 images and the car plate recognition system is implemented by using MATLAB R2016a with the processor Intel Core™ i5-6700HQ CPU @ 2.60GHz of 64-bit Operating System, x64-based processor.

The detail explanation on the implementation of the method is explained as follows. Figure 2 shows that the result of grayscale Image 1 that contains the car plate.

![Figure 2. Grayscale of Image 1.](image)

Then, the grayscale Image 1 is converted to binary using appropriate threshold. Figure 3 shows that the result of binary conversion of the tested car plate Image 1.

![Figure 3. Binary of Image 1.](image)

The output of extraction process is all the regions that have maximum probability of consisting car plate. Out of these regions, the one with the maximum value is considered as the most probably contains the plate number.

Then, the regions that have small area are eliminated in order to ensure the area of car plate is detected. Figure 4 shows that the result of car plate area detection.
Once the detection is done, the detected car plate which is bounded by green box had been cropped. Figure 5 shows that the result of extracted car plate.

In order to proceed on recognizing the car plate, there are several steps which are resizing process, median filtering process, Mathematical Morphology and Template Matching process by using correlation are implemented.

The first step is pre-processing of tested car plate which is resizing, and median filtering. The resizing process is applied to keep the image in the same image ratio and median filtering image is implemented to remove some noise. Then, Mathematical Morphology image processing used are dilation and erosion for edge enhancement.

Figure 6 shows that the car plate that have been dilated and eroded using disk of radius 1 that produced edge detection of each character clearly.

Next step is filling all the regions of the car plate. Each character is filled by the white colours to deal with recognising process. Then, move to another step which is selecting all the regions that are pixel area and remove small area that can make recognising process easier.

Figure 7 shows the filling process on the tested car plate.

It can be seen that number ‘9’ and ‘6’ are filled the inner part. This is because in character recognition, the outer contour is good enough for further process.
In order to recognize each of the characters of the tested car plate, each character is required to be isolated using bounding box segmentation to extract the bounded characters. Figure 8 shows the image segmentation that shown by each character in a box.

![Figure 8. The Segmented Image of Each Character.](image)

The last part is to recognize the detected car plate. It is compared with character of Malaysia standard car plate in template by using Template Matching process. The recognition part includes the process of correlation between the tested image and the characters in the template.

The correlations of the tested image which are *WSX9692* are calculated and correlate with the characters in the template. Figure 9 shows the result of recognition of car plate after Template Matching process.

![Figure 9. The Recognized Car Plate.](image)

4. Results
This study mainly focused on Malaysia standard car plate. Car plate recognition generally consists of four steps which are data collection, detection and extraction car plate, car plate recognition and evaluation of each characters. The study mainly focuses on Malaysia standard car plate. Table 1 shows 5 samples of car plate that are successfully recognized.

| No. | Original Image | Detected Car Plate | Extracted Car Plate | Result |
|-----|----------------|---------------------|---------------------|--------|
| 1   | ![Image 1](image) | ![Image 2](image)   | ![Image 3](image)   | ![Image 4](image) |
Table 2 shows the performance analysis of the 25 images. The car plate images that were correctly detected is 23 from 25 images. Therefore, the success rate of car plates detection is 92%. The unsuccessful plate detection due to the presence of noise, blur and uneven image contrast especially during acquisition.

**Table 2. Performance Analysis.**

| Criteria               | Car Plates Detection | Character Recognition |
|------------------------|----------------------|-----------------------|
| Number of tested images| 25                   | 23                    |
| Number of succeeded images | 23                   | 20                    |
| Percentage of Succeeded | 92%                  | 86.95%                |

While the success rate of character recognition is 86.95% which represents 20 out 23 images were successfully recognized the character.
5. Conclusion
As a conclusion, in order to overcome the problems statement of complex method used in preparing a lot of training needed, this study successfully implemented using Mathematical Morphology and Template Matching techniques on a set of Malaysian car plate.

The accuracy of the method has been evaluated where 23 out of 25 car plate images are successfully detected and 20 of them were correctly recognized using Mathematical Morphology and Template Matching method. The performance of the system shows that the car plate part can be successfully extracted by 92% of original image and effectively recognized by 86.95%.

It is recommended that to use the combination of Canny and Mathematical Morphology in detecting car plate edges in future work that could lead to more clearer, clean and easy to process image. Moreover, it is also suggested to improve the proposed method so that it can be used successfully into the moving car, broken car plate, and unclear car plate image that influence by the contrast.

6. Acknowledgement
The authors would like to express our gratitude to Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Shah Alam for the support and opportunity given in completing this research.

7. References
[1] Maini R and Aggarwal H 2014 Study and Comparison of Various Image Edge Detection Techniques International J. of Image Processing pp 1-12
[2] Zaman N A K, Rahman W E Z W A, Jumaat A K and Yasiran S S 2015 Classification of Breast Abnormalities using Artificial Neural NetworkInternational Conf. on Mathematics, Engineering and Industrial Applications 2014 1660 pp 050038-1-050038-7
[3] Kahar M A, Mutalib S and Rahman S A 2015 Early Detection and Classification of Paddy Diseases with Neural Networks and Fuzzy Logic 17th International Conf. on Mathematics, Engineering and Industrial Applications 2014 1660 pp 050038-1-050038-7
[4] Mutalib S, Abdullah M H, Rahman S A and Aziz Z A 2016 A Brief Study on Paddy Applications with Image Processing and Proposed Architecture 2016 IEEE Conf. on Systems, Process and Control pp 124-129
[5] Jodas D S, Marranghello N, Perieira A S and Guido R C 2013 Comparing Support Vector Machines and Artificial Neaural Networks in the Recognition of Steering Angle for Driving of Mobile Robots Through Path in Plantations International Conf. on Computational Science pp 240-249
[6] Lazrus A and Choubey S 2011 A Robust Method of License Plate Recognition using ANN International J. of Computer Science and Information Technologies pp 1494-1497
[7] Utge M S 2015 A Survey and Comparison of License Plate Recognition using different Classifiers International J. of Computer Applications pp 5-7
[8] Yusoff M, Rahman S A R, Mutalib S and Mohamed A 2007 Kohonen Neural Network Performance in License Plate Number Identification International Conf. on Electrical Engineering and Informatics pp 512-515
[9] Phangtriastu M R, Harefa J and Tanoto D F 2017 Comparison Between Neural Network and Support Vector Machine in Optical Character Recognition 2nd International Conf. on Computer Science and Computer Intelligence pp 351-357
[10] Goyal A, and Bhatia R 2016 Various Techniques for Number Plate Recognition-A Review International J. of Computer Applications pp 25-27
[11] SharmaG 2018Performance Analysis of Vehicle Number Plate Recognition System using Template Matching Techniques J. of Information Technology and Software Engineering 8 pp 1-9
[12] Gilly D and Raimond K 2013 Licence Plate Recognition-A template Matching Method 
*International J. of Engineering Research and Application (IJERA)* pp 1240-1245

[13] Ratchatasriprasert B, Kongpan K, Punyarprateep P and Yingthawornsook T 2012 License Plate 
Detection Based on Template Matching Algorithm *International Conf. on Computer and 
Communication Technologies* pp 139-143

[14] Ansari N N, and Singh K A 2016 License Number Plate Recognition using Template Matching 
*International J. of Computer Trends and Technology (IJCTT)* pp 175-178

[15] Embong R, Aziz N M N A, Karim A H A and Ibrahim M R 2017 Colour Application on 
Mammography Image Segmentation *J. of Physics: Conf. Series* 890 pp 1-7