A Real-Time Malaysian Automatic License Plate Recognition (M-ALPR) using Hybrid Fuzzy

Wisam Al Faqheri and Syamsiah Mashohor

Dept. of Computer and Communication Systems
Faculty of Engineering
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor Darul Ehsan, Malaysia

Abstract
The Road Transport Department of Malaysia has endorsed a specification for car plates that includes the font and size of characters that must be followed by car owners. However, there are cases where this specification is not followed. This paper proposes a new methodology to segment and recognize Malaysian car license plates automatically. The proposed methodology solves the problem of segmenting different length licenses such as license with different number of character and number. There are two main objectives for this paper: first is to develop fuzzy rules to recognize the segmented characters and numbers from the same input-sets, which is the same size without overlapping between the characters and numbers sets. Secondly, this paper proposes a method to recognize non-standard plates by Template Matching theorem. Finally, the hybrid method of Fuzzy and Template matching is tested on 300 samples of car images captured in outdoor environment. The results yield 90.4% recognition accuracy, the Fuzzy based required 1.7 seconds and Template matching based took 0.75 seconds to perform the recognition. The adaptability factor of the hybrid method is also discussed.
Key words:
Automatic license plate recognition, Fuzzy logic system, Template matching theorem.

1. Introduction

A lot of image processing techniques which invented and discussed several years ago have found their way now to enter the real life fields, especially the Intelligent Transportation System (ITS) [1]. One of the most important topic of ITS is the license plate recognition. License plate recognition systems have been physically utilized in many facilities, such as parking lots [2, 3], security control of restricted areas [4], traffic law enforcement [5], congestion pricing [6], and automatic toll collection [7]. Due to the rapidly increase in number of vehicles across the world's big cities and one of them is Kuala Lumpur (capital of Malaysia), license plate recognition system has become one of the most important digital image processing systems to be used. This system will solve so many problems for this city facilities which is hard to be controlled by human 24 hours. However, this system still facing a lot of difficulties to be able to recognize license plates and one of these difficulties is the large variety of plate's layouts between the different countries and even across the same country cities. In Malaysia, there are more than ten different forms that have minor or major differences between them. This project tends to find one integrated system which can recognize these license forms automatically in real-time processing.

2. Background

A large and growing body of literature has been investigated and published on the Artificial intelligence and specially the license plate recognition (LPR). This field and its application attracted many researchers to search and develop systems which can process images and get the useful information from them. This task is challenging due to the diversity of plate formats and the nonuniform outdoor illumination conditions during image acquisition [8]. The cause for poor performance of these systems can be unsuitable light conditions, noisy patterns connecting characters and poor edge enhancement [9].
Several techniques have been used to implement that job such as artificial neural network [10, 11, 12, 13, 14, 15]. These studies have shown quite good accuracy but long processing time and it needs periodical training for better accuracy. Template matching theorem [16, 17, 18] has been used widely in recognizing the segmented characters and numbers. Template matching showed high accuracy but requires efficient searching method and it needs large storage area to save all the numbers and characters templates. In other major studies, Fuzzy logic system [19, 20] has been used to recognize the plate's segmented elements. This system shows high performance, accuracy and short processing time. However, it's sensitive for the noise and distortion. Thresholding techniques [21, 22] have been investigated to segment and recognize license plates. Many other techniques have been used such as stroke analysis [23] and color license plate image segmentation and recognition [24]. In [25], the author proposed a novel method to recognize license plate which

Manuscript received February 5, 2009
Manuscript revised February 20, 2009

captured by video camera and implemented it on an embedded platform.

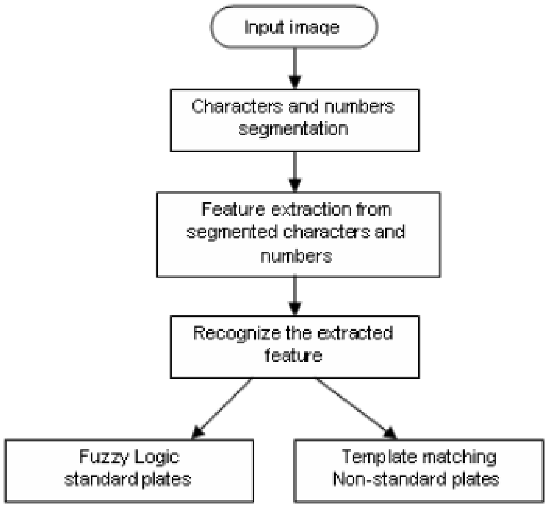

Figure 1: System flow chart

These methods can be broadly classified into iterative and noniterative approaches. There is a tradeoff between these two groups of approaches; iterative methods achieve better accuracy, but at the cost of increased time complexity. In this study, we try to balance between the high accuracy and decrease the time complexity by hybridizing two approaches, Fuzzy logic and Template matching theorem. Some researches which have been done to design a suitable ALPR for Malaysian car [23, 26] have focused on the standard license plates only. The proposed system designed to cover the standard and non-standard plates. The methods employed in this system are fast with high accuracy and that support the proposed system to be a real time ALPR system.
This paper will focus on two objectives. The first one is to recognize the standard plates using Fuzzy logic system. The second one is to recognize non-standard plates by using Template matching theorem employing sum of squared difference. This paper is organized into four parts. The first part deals with introducing the main idea of this work and presents the related works. The second section will show the methodology of the work and how it has been implemented. The third part presents the results and the fourth is the conclusions and future work.

3. Methodology

The flow chart of the proposed system is shown in Figure 1. First step is segmentation, feature extraction and recognition of the extracted feature. The extracted feature will be forwarded to fuzzy based or template based depends on the category of the extracted feature.

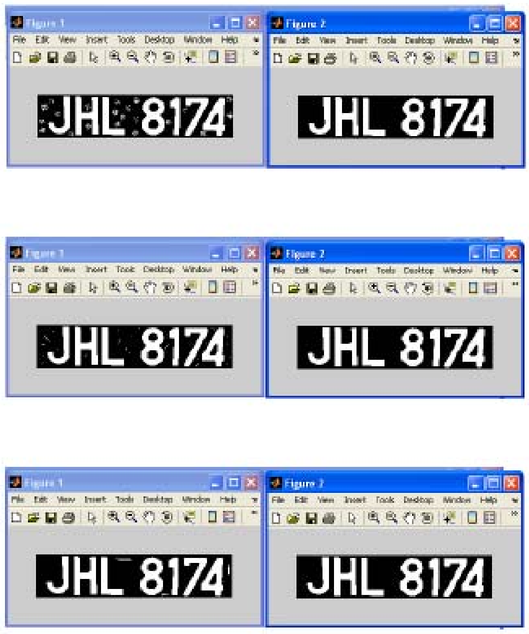

Figure 2: Preprocessing results

3.1 Preprocessing

Preprocessing is a very important step to enhance plate image quality for better segmentation and recognition. Choosing the right preprocessing techniques depends not only on the quality and the problems found in the captured images but also on the recognition algorithm that follows. In our proposed system, a preprocessing step is applied for the license plate binary image:

3.1.1 Removing small objects (noise)

During the thresholding processing on a gray scale image, many small objects or points accrue in the thresholded image due to the problem of different illumination, low quality cameras and motion effect. This kind of noise give direct effect on segmentation and recognition process. We have used a morphological process which search the entire image for small connected elements and remove it. We have set the maximum size of connected element to be removed to 50 pixels. The whole preprocessing results can be viewed in Figure 2.

3.2 Segmentation algorithm

Segmentation is the step where plate's elements (characters and numbers) are being extracted from the plate's background. This step contains several operations as the sequence below:

3.2.1 Standard and nonstandard plate testing

This test is performed to determine the plate is a standard or nonstandard plate. As mentioned before, Malaysian license plates have different forms and to simplify the proposed system, we have divided them into two groups (see Figure 3):

(a) (b)

Figure 3: (a) Standard license plate and (b) Non-standard license plate

1. Standard license plate: This is the form of plates which consist of standard capital English characters (number of characters vary from one character to three characters maximum) and standard numbers.

2. Non-standard license plate: The first part of this form consists of a special word represents the place where the car has been registered like Putrajaya, or car model like Proton, Satria and Perodua. The second part represents car registration number.

Standard and non-standard test is performed by a vertical scanning on the input plate image. As discussed before, non-standard plates contain more characters than the standard plates which contain maximum of three characters. The test will account the first characters, if it is three or less, then the plate is standard and it will be recognized by Fuzzy system. If it is more than three characters, then the plate is nonstandard plate and has to be recognized by template matching theorem.

3.2.2 Detection of first and last columns for each character and number

For the standard plates, the second operation of segmentation step will be the detection of first and last columns for each character and number to cut it off from the background. The operation of first and last columns or rows detection could be influenced by many conditions that happen during the plate acquisition step such as uneven illumination, blurring and slope. As shown in Figure 4, slope could lead to wrong detection for the first and last row for the plate. Therefore, we have improved our first approach [27] where vertical scanning to detect first and last columns for each character and number is conducted before horizontal scanning as explained in Algorithm 1. This improvement will reduce the error of first and last columns and rows which has been encounted using our first approach. Vertical scanning (column by column) will be done to detect the first and last columns or each component and cut the area in between to separate the license information from background (see Figure 5(a)).

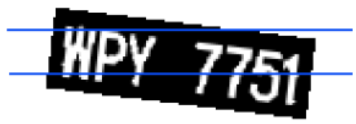

Figure 4: The influence of acquisition slope on horizontal segmentation

(a) (b)

Figure 5: Segmentation process: (a) Vertical segmentation for the original plate image and (b) Horizontal segmentation for the extracted image

Algorithm 1 Vertical segmentation

```
input plate image
r=0
 for i=1 to last columns
  if pixel(i)= white, then r=r+1
  end
  if r>threshold, then i is the first columns
s=0
 for l= i to last columns
  if pixel(l)=white, then s=s+1
  end
  if s< threshold, then l is the last columns
f= image between i and l
```

Algorithm 2 Horizontal segmentation

```
input f
m=0 n=0
 for t=first row to last row
  if pixel(t)= white, then m=m+1
  end
  if m>threshold, then i is the first row
   for c= i to last row
    if pixel(c)=white, then n=n+1
    end
     if n< threshold, then l is the last row
d= image between i and l
```

3.2.3 Remove upper and lower extra areas of each component

After the first and last columns of the component have been detected, horizontal scanning will be done to detect the first and last rows from the result of the previous step and the whole process is described in Algorithm 2. The result of this operation will be an image which contains only the character or number without any extra area. This result will help to extract image features easily (see Figure 5(b)) in the later stage.

3.3 Features extraction

Features extraction is the step where specific information will be extracted from each character or number image which resulted from segmentation step. This operation contains the following steps:

3.3.1 Euler number calculation

First step is to calculate the Euler number for each character and number image. The Euler number is equal to the number of connected elements (always equal to one) minus the number of holes. Three groups will result from this step as following [19]:

1. Euler number equal to 1 - This group contains C, E, F, G, H, I, J, K, L, M, N, S, T, U, V, W, X, Y and Z. It also contains the numbers 1, 2, 3, 5 and 7.

2. Euler number equal to 0 - This group contains A, D, O, P, Q and R and it contains number 4, 6 and 9.

3. Euler number equal to -1 - This group only contains character B and number 8.

It is clear that this grouping process will increase system accuracy of recognizing characters and numbers and it will also reduce the time of recognition process.

3.3.2 Extracting image features

After grouping process is completed, the system will extract specific information from each group. For example, the system will determine whether the following positions are off or on (white or black) for Group 1 members (Euler number=1): Upper Left Corner (ULC), Upper Center (UC), Upper Right Corner (URC), Center Left (CL), Center Center (CC), Center Right (CR), Lower Left Corner (LLC), Lower Center (LC), Lower Right Corner (LRC) and it will also find how many transitions from on to off or from off to on will happen if a vertical and horizontal lines pass through the center of the image (refer to Figure 6).

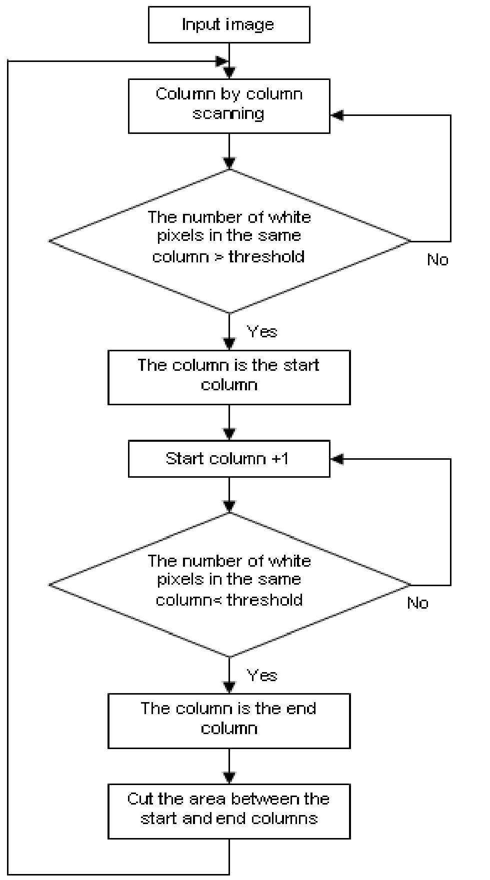

Figure 6: Flowchart of vertical segmentation

The above information are the inputs for Fuzzy system [19]. Fuzzy system depends on the input information to decide which character or number under study and the system will give the final result. The result of feature extraction step will be one dimension matrix which contain elements equal to the features extracted from each group. These elements will have specific sequence to be recognizable to Fuzzy logic system. As example for group one (Euler number equal to 1) the matrix will be as below:

Outmat1=[ULC UC URC CL CC CR LLC LC LRC]

In addition, vertical and horizontal counter are added to the input of Fuzzy logic system with the above matrix. The above matrix will be smaller for group two (Euler number equal to 0) because of the lower number of elements in this group. The output matrix for group two will be as below:

Outmat2=[ULC URC LLC LRC]

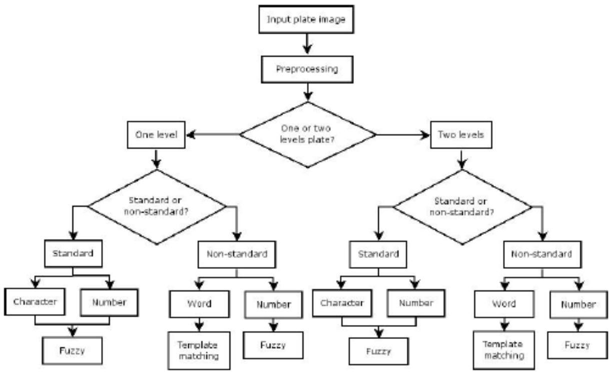

Figure 7: Flowchart of the hybrid Fuzzy system

In addition, vertical counter will be added to the above matrix as an input to Fuzzy logic system. Feature extraction step finish once the output matrix has been extracted from each element in the image and the recognition step will start.

3.4 Recognition algorithm

Recognition step is the last operation in the system where the input from the feature extraction operation is being translated and understood by the system. As mentioned before, the large variety of Malaysian car plate forms make it so hard to recognize all the form by the same system with the same accuracy. Therefore, we have integrated these two methods in this system for better recognition accuracy, lower computing time and better adaptability factor. Recognition step will be divided into two phases: recognition by Fuzzy logic system for standard plates, and recognition by template matching
for non-standard plates (see Figure 7).

3.4.1 Fuzzy logic system

One of the most important specification that nominate Fuzzy system to recognize standard plates is that it has high accuracy and speed which suits real time system requirements. After the output matrix extracted from feature extraction step, it will be the input of Fuzzy logic system where the system will try to understand the inputs represent which character or number. For example, if the output matrix is as below:
Outmat=[1 1 1 0 1 0 0 0 0], vertical counter equal to 2 and horizontal counter equal to 2 then the character is W.
After all characters and numbers are recognized by the system, it will show the output as the sequence of the input (see Figure 8). Adaptability is one of the most important features that ALPR need to have in order to be applicable in Malaysia. This adaptability feature is shown in our system by three specifications. First is the ability to recognize different length of license plates. The number of

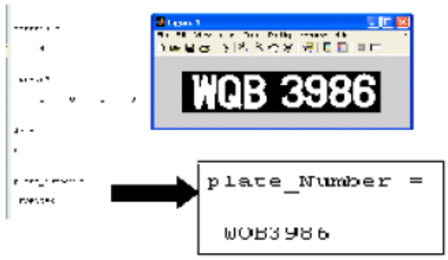

Figure 8: Output of standard license plate

Characters in Malaysian plates vary from one to three characters maximum while the numbers vary from one to four maximum. These varieties caused confusion to the systems which only can recognize the fixed quantities of characters and numbers in plates. The proposed system has the ability to recognize this variety. Moreover, representing the numbers and characters using the same Fuzzy input-set enable the system to recognize the plate's elements without the need to know if the element under process is a character or a number. Lastly, we represented the characters and numbers with more than one sets to give the flexibility to this system to recognize different shapes and fonts to the same character or number. The proposed design made the proposed system more suitable and applicable in Malaysia.

3.4.2 Template matching theorem

The pattern matching technique is a suitable technique for the recognition of single-font, not-rotated, and fixed-size characters. Although this method is preferably used in binary images, properly built templates also obtained very good results for gray-level images [8]. One of the most important specifications for LPR is to have high speed processing and high recognition accuracy to be a real time system. Therefore, we have to reduce the processing time that system needs to segment long words like Putrajaya or Proton. Moreover, segmentation of these words will also lead to decrement of the recognition accuracy because they are written in Italic font which is hard to be segmented. Employing Template matching theorem (sum of square difference) gives high recognition accuracy and reduce the processing time to segment these words. The only disadvantage is that we need bigger memory area to store the template of words that we need to recognize. We have set a threshold of maximum accepted difference for the program. So it also can recognize if the words are blurry [27]. Moreover, we have used small image as a template

for all words with dimensions of 142 x 252 black and white image (see Figure 9).
The method applied is accounting the sum of squared difference in each position while the word image we want to recognize moves over the background template. The point where the sum of squared difference is less than the threshold will be considered as the point of matching. The program will decide the recognized word up to the dimen-

Figure 9: Background template for non-standard words

Figure 10: Samples of car image acquired

sions of matching position. Referring to Figure 9, the word of image have been positioned vertically over the template image. The word image that we need to recognize will be placed vertically over the template and the sum of squared difference in each position between the word image and the template is measured. Whenever the difference is less than the threshold, the program will find the point of match lie within word area over the template and will print out that word as the output.

4. Experimental Setup

We have used these equipments to implement this project which are Dell 6400 laptop with 1.7GHz Dual-Core processor and 512M of RAM, Logitech webcam with 2Mp resolution and Matlab 6.0 with image processing tools. 300 samples are used for system evaluation and they are acquired from the real scene around the campus of Universiti Putra Malaysia. The samples of these images are shown in Figure 10.

5. Results & Discussion

The main objective for this paper is to provide an input image of license plate that have been extracted from an image of real scene using VEDA [28], then segment the characters and numbers and recognize it. This process has to cover forms of Malaysian license plates. The results and discussions are presented in three phases: recognition accuracy, processing time and system adaptability.

Data	Quantity
Number of real-scene samples	300
Number of correct segmentation	294/300
Number of correct recognition	271/294
Recognition accuracy rate	90.4%

Table 1: Recognition accuracy rate of the hybrid method on real-scene images

5.1 Accuracy

Among many methods that have been used for image recognition, Fuzzy logic system and matching theorem are the most accurate and efficient theorems and hence we used these two system for a real time processing system which need high accuracy and fast processing to be applicable in the real fields. From the experiments, the hybrid system shows almost 100% accuracy in the testing of good quality images which have been captured without blur or with low-level of noise. Referring to Table 1, this accuracy reduced to 90.4% for the images that have been captured in outdoor environment without blur but with slope during image acquisition. Therefore, the recognition inaccuracies occured due to the sloped plates in real-scene images which acquire skew correction process before the recognition take place. The results show high recognition accuracy result on the hybrid method which is 100% for the ideal plates and 95.5% for the noisy and blurry images.

5.2 Processing time

The processing time for a real time processing system still one of the most important specification that it should have. We have improved several steps to reduce the processing time for the minimum value. Fuzzy system takes maximum of 1.7 seconds to process one plate starting from segmentation to the recognition and displaying the results. Template matching takes maximum of 0.75 second to recognize a blurry plate, hence the non-blurry plate can be recognized faster than that.

5.3 Adaptability

The different length of license plates (different number of numbers and characters) is the major problem faced by ALPR system in Malaysia. To avoid this problem, we proposed a tailored design that enable the system to segment and recognize different types of license. The adaptability feature also can recognize if a license plate is standard plate or not. For now, this feature is able to recognize eight different types of license layouts (see Figure 11). After the recognition of

Figure 12: License plates forms

the standard or non-standard plate, the system will direct the plate to be recognized by Fuzzy system if it is a standard or by template matching if it is a non-standard license plate.

6. Conclusion

By comparing with other systems which mostly failed to recognize all forms of Malaysian license plates due to the large varieties in the forms of these plates, the proposed system which is a hybrid method is able to recognize all Malaysian plate forms. The hybrid method has achieved good performance for real time recognition system. Most of the previous work relied on a single method like template matching or neural network which is ideal to recognize some forms while they showed weak recognition results to the rest of the forms. It is evident that the number and quality of testing examples have a direct effect on the overall LPR performance. However,
this factor is often ignored in performance evaluation
or comparison, which is the appropriate criterion for an algorithmic assessment as highlighted in [8]. In future, the proposed hybrid system will be tested on the standard database as proposed by [8].

7. Acknowledgement

This research is supported by Higher Learning Education Ministry of Malaysia, under the Fundamental Research Grant No. 5523427.

References

[1] H. Yang, L. Xu, and L. Shi, "Design and implementation of license plate recognition system," in First IEEE International Symposium on Information Technologies and Applications in Education,ISITAE '07., pp. 602 – 605, 2007.
[2] T. Sirithinaphong and K. Chamnongthai, "The recognition of car license plate for automatic parking system," in Proc. 5th Int. Symp. Signal Processing and its Applications, pp. 455–457, 1998.
[3] N. H. C. Yung, K. H. Au, and A. H. S. Lai, "Recognition of vehicle registration mark on moving vehicle in an outdoor environment," in IEEE Int. Conf. Intelligent Transportation Systems, pp. 418–422, 1999.
[4] S. Draghici, "A neural network based artificial vision system for license plate recognition," Int. J. Neural systems, vol. 8, pp. 113–126, 1997.
[5] P. Davies, N. Emmott, and N. Ayland, "License plate recognition technology for toll violation enforcement," in Inst. Elect. Eng. Colloquium Image Analysis for Transport Applications, pp. 711–715, 1990.
[6] J. R. Cowell, "Syntactic pattern recognizer for vehicle identification numbers," Image and Vision Computing, vol. 13, no. 1, pp. 13–19, 1995.
[7] R. A. Lotufo, A. D. Morgan, and A. S. Johnson, "Automatic number plate recognition," in Inst. Elect. Eng. Colloquium on Image Analysis for Transport pplications, pp. 611–616, 1990.
[8] C. E. Anagnostopoulos, I. E. Anagnostopoulos, I. D. Psoroulas, V. Loumos, and E. Kayafas, "License plate recognition from still images and video sequences: A survey," IEEE Transactions on Intelligent Transportation System, vol. 9, no. 3, pp. 377–391, 2008.
[9] M. Cinsdikici and T. Tunah, "License plate segmentation for intelligent transportation system," in 18th International Symposium on Computer and Information Sciences (ISCIS 2003), pp. 439–446, 2003.
[10] M. Fukumi and Y. Takeuchi, "Neural network based threshold determination of malaysian license plate character recognition," in Intelligent Signal Processing and Communication Systems (ISPACS 2004), pp. 771– 775, 2004.

[11] A.Broumandnia and M. Fathy, "Application of pattern recognition for farsi license plate recognition," International Journal on Graphics, Vision and Image Processing, vol. 5, pp. 25–31, 2005.
[12] H. A. Qodri and S. Sardy, "Plate number recognition by using artificial neural network," in Prosiding Semiloka Teknologi Simulasi dan Komputasi serta Aplikasi, 2006.
[13] M. H. T. Brugge, J. H. Stevens, J. A. G. Nijhuis, and L. Spaaancenbrug, "License plate recognition using dtcnns," in 5th IEEE int. workshop on Cellular Neural Networks and Their Application, pp. 212–217, 1998.
[14] R. Parisi, E. D. D. Clsudio, G. Lucarelli, and G. Orlandi, "Car plate recognition by neural networks and image processing," in IEEE int. Symp. Circuits and systems, vol. 3, pp. 195–198, 1998.
[15] K. K. Kim, K. I. Kim, J. B. Kim, and H. J. Kim, "Learning-based approach for license plate recognition," in IEEE signal Processing Society workshop, vol. 2, pp. 614–623, 2000.
[16] D. Chanson and T. Roberts, "License plate secognition system." www.manukau.ac.nz./EE/research /2002/dc.pdf, 2002.
[17] J. D. Tubbs, "A note on binary template matching," Journal of Pattern Recognition, vol. 22, pp. 359–365, 1989.
[18] P. Comelli, P. Ferragina, M. N. Granieri, and F. Stabile, "Optical recontion of motor vehicle license plates," IEEE Transactions of Vehicle Technology, vol. 44, no. 4, pp. 790–799, 1995.
[19] M. Alata and M. A. Shabi, "Text detection and characters recognition using fuzzy image processing," Journal of Electrical Engineering, vol. 57, no. 5, pp. 258–267, 2006.
[20] J. A. G. Nijhuis, M. H. T. Brugge, K. A. Helmholt, J. P. W. Pluim, L. Spaanenburg, R. S. Venema, and M. A. Westenberg, "Car license plate reconition with neural networks and fuzzy logic," in IEEE Int. Conference on Neural Networks, vol. 5, pp. 2232–2236, 1995.
[21] Y. Zhang and C. Zhang, "New algorithm for character segmentation of license plate," in IEEE Intelligent Vehicles Symposium, pp. 106–109, 2003.
[22] V. Shapiro, D. Dimov, S. Bonchev, V. Velichkov, and G. Gluhchev, "Adaptive license plate image extraction," in International Conference Computer Systems and Technologies, pp. 1–7, 2004.
[23] A. Sehgal, "Design of a recognition system for special malaysian car plates using stroke analysis," Master's thesis, Unversiti Teknologi Malaysia, 2005.
[24] E. R. Lee, P. K. Kim, and H. J. Kim, "Automatic recognition of a car license plate using color image processing," in IEEE International Conference Image Processing (ICIP-94), vol. 2, pp. 301–305, 1994.
[25] B. Lim, W. Yeo, K. Tan, and C. Y. Teo, "Dsp based real time character classification and recognition for car plate detection and recognition," in IEEE Conference on In-Circuit Serial Programming (ICSP), pp. 1269– 1272, 1998.
[26] S. N. H. S. Abdullah, M. Khalid, R. Yusof, and K. Omar, "Comparison of feature extractors in license plate recognition," in First Asia International Conference on Modelling & Simulation (AMS'07), pp. 502– 506, 2007.
[27] W. A. Faqheri and S. Mashohor, "Malaysian Automatic license plate recognition (m-alpr)," in Proceedings of 2008 Student Conference on Research and Development (SCOReD 2008), vol. 1, pp. 190–193, 2008.
[28] A. M. Al-Ghaili, S. Mashohor, A. Ismail, and A. R. Ramli, "A new vertical edge detection algorithm and its application," in IEEE International Conference on Computer Engineering & Systems (ICCES 2008), pp. 204–209, 2008.

Wisam S. Hussein Al Fakhri was born in Basrah, Iraq on March 30th, 1983. He received the Bachelor in computer engineering in 2005 from Engineering University of Basrah, Iraq. In December 2007, he joined University Putra Malaysia, to further his master study on computer vision and image processing.

Syamsiah Mashohor received her B.Eng degree from the Department of Computer and Communication Systems Engineering, Universiti Putra Malaysia (UPM) in 2002. Then, she continued her study for PhD at Department of Electronics and Electrical Engineering, University of Edinburgh, UK and graduated in 2006. She is a member of IEEE since 2007 and involved in Society of Computational Intelligence. From 2002 until 2006, she was a tutor at Department of Computer and Communication Systems Engineering, UPM and now she has been appointed as a senior lecturer. Her field of specialization is artificial intelligence especially Genetic Algorithms and she also involves with wide area of interest in image processing. She has taught a range of computing topics and is particularly interested in teaching programming and image processing.