License Plate Extraction and Recognition of a Thai Vehicle Based on MSER and BPNN

Tao Hong
Faculty of Science and Technology
Assumption University
Bangkok, Thailand
htao.tony@gmail.com

Anilkumar Kothalil Gopalakrishnam
Faculty of Science and Technology
Assumption University
Bangkok, Thailand
anil@scitech.au.edu

***Abstract*—The extraction and recognition of a Thai vehicle license plate based on Maximally Stable Extremal Regions (MSER) and Back-Propagation Neural Network (BPNN) is presented. The license plate area is in a maximally stable extremal region of a car image. It can be effectively extracted from MSERs by multiple classifications. The feature extraction of characters from the license plate is based on Zernike moment. The feature is used as a training dataset for the BPNN to recognize the characters. The experimental results indicate that the proposed approach is an effective method for the extraction and recognition of a Thai license plate.**

Keywords-Thai license plate recognition; MSER; Zernike moment; BPNN

I. INTRODUCTION

With rapid economic development and urban expansion, transportation volume increased year by year. The traffic management has also become more complex. In order to alleviate traffic pressure and improve vehicle management efficiency, Intelligent Transportation System (ITS) plays an important role in traffic management. The Vehicle License Plate Recognition (VLPR) is already widely applied in intelligent transportation system. For example, traffic surveillance system, highway management, vehicle location and navigation, parking management system [1], etc.

Vehicle license plate recognition is mainly divided into three parts: license plate location, character segmentation and character recognition. License plate location is the most important part of license plate recognition. The quality of the license plate location directly influences the outcome of the license plate recognition. In the natural light, the license plate location needs to overcome uneven illumination, license plate tilted angle, complex background conditions, etc. In this paper, the method which is used for the license plate location is mainly based on the MSER algorithm and multiple classifications. The character segmentation is based on the characteristics of MSER and priori knowledge of a license plate which is common in Thai private cars. It is due to the similarity of some Thai characters, the recognition of them are quite difficult with standard techniques. The application of Zernike moment is sensitive to the deformation of characters in the image. Hence the character recognition is based on the Back-Propagation Neural Network (BPNN) combines with Zernike moment.

The rest of the paper is organized as follows. Section II briefly describes literature review in the related work. The structure of VLPR system is introduced in section III. The detail of license plate location is presented in section IV. Section V explains the character segmentation and classification. The character recognition steps are presented in Section VI. Section VII explains the evaluation of the experimental results and performance of VLPR system. Finally, the conclusion and future works are in section VIII.

II. RELATED WORK

From the literature review, it is studied that a lot of license plate location methods based on MSER. The Maximally Stable Extremal Regions algorithm is proposed by J.Matas [2]. J.Matas also introduces an unconstrained license plate detection by Category-Specific Extremal Region (CSER) in [3]. A method of license plate detection is implemented by MSER+ and MSER- in [4]. In [5], the license plate is extracted from MSERs by the priori knowledge of license plate. A novel license plate location is based on the arrangement of MSERs in [1].

For Thai license plate recognition, the essential element of Thai characters is used for the Thai license plate recognition in [6]. The off-line Thai car license plate is recognized by the Hausdorff distance technique [7]. In [8], a position varied Thai license plate recognition is based on BPNN. The template matching technique is used to recognize the Thai license plate from a video stream [9]. In [10], an Extreme Learning Machine (ELM) is adopted for the Thai license plate recognition system. These methods have high requirements for the capturing position, camera angle, light, etc. The character recognition techniques are also difficult to overcome similarity of Thai characters.

III. SYSTEM OVERVIEW

The structure of the vehicle license plate recognition system is shown in Fig.1. The System is mainly divided into three parts: license plate location, character segmentation and character recognition. First of all, the High Resolution (HR) image of the vehicle is converted to Low Resolution (LR) image with a proportional value for license plate location. The part of license plate location consists of the image preprocessing, MSER detection and multiple classifications. After the license plate location, the coordinates of license plate in LR image are enlarged by same proportional value in first step. Then the

978-1-4799-6049-1/15/$31.00 ©2015 IEEE

enlarged coordinates are used to extract the license plate from HR image. The part of character segmentation separates the Thai characters and numbers from the license plate and divides the characters into a set of isolate binary character images. These isolate character images are normalized for the preparation of feature extraction by Zernike moment. The BPNN uses these features for training and recognizing. Finally, Thai characters and numbers are recognized by the BPNN.

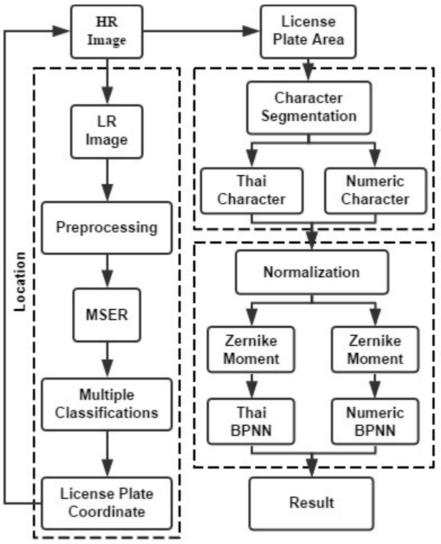


Figure 1. The structure of VLPR system.

IV. LICENSE PLATE LOCATION

A. Object Feature

There are different types of vehicle license plate in Thailand. The background color of a car license plate indicates the nature of a vehicle. For example, the temporary license plate is the black font in the red background, the taxi license plate is the black font in the yellow background, etc. This paper focuses on Thai private car license plate with a complex background is shown in Fig.2. The private car license plates are indicated with the black font in the white background.

Figure 2. License plate image.

In the complex background, the presence of asymmetrical illumination, shadow, billboards and artificial structures make the interference regions increase. Too many interference regions lead to increase the amount of calculations. This factor increases the difficulty of the license plate localization. In order to extract the license plate area from a car image with complex background effectively, a robust image processing algorithm must be needed to overcome the mentioned interference factors.

The size of a Thai private car license plate without its frame is 15 by 34 centimeters. The license plate consists of two Thai characters and one to four decimal numbers (the decimal numbers are from 1 to 9999, zero will not appear in the beginning). After 2012, the license plate converted to the new format "1กข 1234", to retain the original license plate size, but reduces the size of the font. The actual measurement value of the license plate under the plate's frame is shown in Fig.3. Some edges are covered by the frame. Therefore, the size of license plate reduces to 12.5 by 33.2 centimeters.

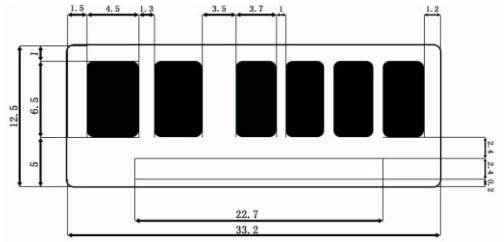


Figure 3. License plate structure.

B. Maximally Stable Extremal Regions

In computer vision, the maximally stable extremal regions (MSER) are used as a method of blob detection in images. The concept of MSER can be explained by thresholding. That is, the image is binarized through a range of threshold values. The gray level value of each pixel is detected based on a threshold value. The pixels below the threshold are "black" and above and equal are "white". If a sequence of thresholded images I_t with frame *t* corresponding to threshold *t*. First of all, the image is all white, then 'black' spots corresponding to local intensity minima will appear then grow larger. These 'black' spots will eventually merge, until the whole image is black [2]. The set of all connected components in the sequence is the set of all extremal regions. Let $Q_1, \ldots, Q_{i-1}, Q_i$ be a sequence of nested extremal regions $(Q_i \subset Q_{i+1})$. The extremal region Q_i is maximally stable if and only if the equation (1) has a local minimum.

$$q(i) = \frac{|Q_{i+\Delta} \backslash Q_{i-\Delta}|}{|Q_i|} \quad (1)$$

The symbol Δ means that the step length of the threshold. The equation checks for regions that maintain unchanged shapes over a large set of thresholds. If a region $Q_{i+\Delta}$ is not significantly larger than a region $Q_{i-\Delta}$, region Q_i is taken as a maximally stable region.

There are four MSER properties [2]. i) Invariance to affine transformation of image intensities. ii) Covariance to adjacency preserving. iii) Sability. iv) Multi-scale detection. The set of all extremal regions can be enumerated in $O(n\log\log n)$, where *n* is the number of pixels in the image. This paper would make use of these four properties of MSER algorithm for the research.

The MSER algorithm extracts the maximally stable extremal regions and then uses the ellipse to fit these extremal regions are shown in Fig.4. Each elliptical area represents a maximally stable extremal region. There are some small ellipses in the license plate area. These ellipses are corresponding to the license plate characters. This feature will be used to locate the license plate. At the same time, some areas also become the interference areas in the image. For example, headlight, car logo, car grille, doors and windows on the building, car body front, roadside billboards, etc.

Figure 4. Maximally stable extremal regions.

The MSERs of the image are extracted for both MSER+ and MSER- [4]. The MSER+ detects bright regions with dark boundary (bright-on-dark regions) is shown in Fig.5 (a). The MSER- detects dark regions with bright boundary (dark-on-bright regions) is shown in Fig.5 (b).

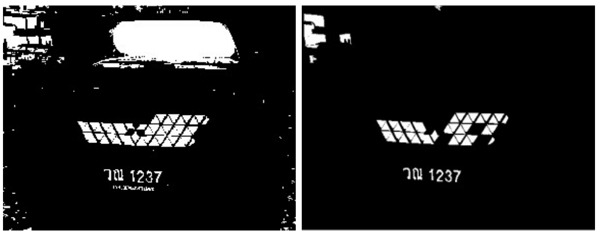
(a) MSER+ (b) MSER-

Figure 5. Two types of MSERs.

C. Image preprocessing

The images of the car are captured by high-resolution format. If these images are directly used for license plate location, it will greatly increase the amount of computational time. In order to reduce the complexity of license plate location, these images are compressed and normalized. Width of the image is unified to 500 pixels, and the length is reduced by the same proportion. It not only ensures the undistorted images, but also keeps the same proportion of license plate area (1%-10%) in the total image space.

In natural light, if the light is too strong in the car image background, it will easily lead to increase the number of interference regions in the image. Hence the original car image undergoes a strong light elimination by constructing elements of the OPEN operation. Then the image by the OPEN operation subtracts with the original image to generate a new image. It effectively eliminates the strong light in the background.



(a) MSER mixed image (b) After elimination

Figure 6. MSER image processing

The license plate extraction is based on MSER+ and MSER-. According to the actual situation of the license plate image, the MSER+ and MSER- have different parameter adjustments. The binary image MSER+ is inverted and represented by the matrix M_1 and the binary image MSER- represented by the matrix M_2. The result of AND operation on M_1 and M_2 $(M_1 \cdot M_2)$ is shown in Fig.6 (a).

In order to eliminate some part of the interference regions and reduce the unnecessary amount of computation, each MSER is marked by 4-connected regions. Every region is calculated length, width, length-width ratio and area. The elimination is based on the priori knowledge of Thai private car license plate. If the region is not satisfied the features of characters in the license plate, it will be eliminated. For example, the length of a region is not larger than its width, the length-width ratio of a region is unreasonable, the region area is too small or too large, etc. The eliminated result which has a few interference regions is shown in Fig.6 (b).

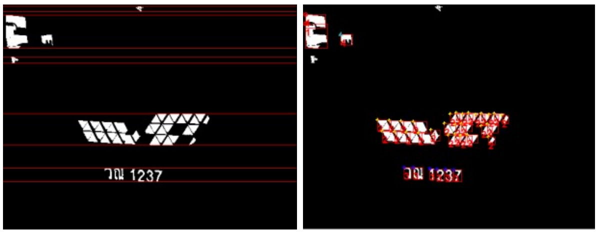
D. Multiple classification

First of all, the horizontal classification is according to the characteristics of normal capturing of the license plate images is shown in Fig.2. The license plate angle must be between -30 to 30 degrees in range, and the distribution of license plate characters must be close to the horizontal distribution. The horizontal projection of license plate characters is a continuous shape. The classification marks the nonzero pixels area in the horizontal projection and uses up-line and down-line to separate no pixels' areas with the pixels' area is shown in Fig.7 (a).The horizontal classification classifies the pixel area to a class based on the up-line and down-line partition.

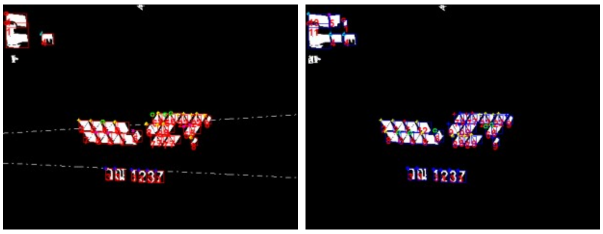
The vertical classification is based on the result of horizontal classification. The spacing of license plate characters is not larger than 4 times of its width. For each horizontal classification, take the center of 4-connected regions. According to the X coordinate of the regional center point, the spacings between the regions are calculated in their descending order. If the spacing is consistent with the features of license plate character spacing, it will be divided into a class. Because of the minimum number of character of the Thai private car license plate is three. Therefore, the number of characters in each vertical class must be at least three regions. The result of vertical classification is shown in Fig.7 (b).

The linear classification is based on the result of the horizontal and vertical classification. In normal circumstances, the distribution of center point of license plate characters is close to a straight line. But because of the special nature of Thai character, the classification chooses the point on the upper left corner of 4-connected regions for the linear classification. Then to find a fitting straight line for these points by the least squares method is shown in Fig.7 (c). After that, calculate the distance from each point to the fitting line. If the distance is more than a threshold value, the region where this point belongs to will be classified as a new class. The remaining points use the least square method to get a new fitting line and calculate the distance from each remaining point to the fitting line again, until no new class is generated.

The height classification is based on the result of above classification processes. In the car image, the height variation of adjacent license plate characters is not more than a character length. Based on the result of above classifications, calculate the average height of each class. If the difference between a height of 4-connected region and the average height of its class is not in the range -10% to 10% of the average height, it will be assigned to a new class. The remaining 4-connected regions in this class calculate the average height and height difference for each region again, until no new class is generated. The result of height classification is shown in Fig.7 (d).



(a) Horizontal classification (b) Vertical classification



(c) Linear classification (d) Height classification

Figure 7. Region classification.

E. License plate extraction

Finally, the reserved classes that contain the number of 4-connected regions are more than three as a candidate region. Then each candidate region needs to calculate the following parameters: the tilted angle a, the length-width ratio of candidate region p, the linear correlation coefficient r, the interval correlation coefficient k and average interval width ratio u for each candidate region.

The tilted angle a that is the angle between a fitting straight line and the X-axis. It must be between the -30 to 30 degrees. The p is obtained from the length and width ratio of the candidate region.

The linear correlation coefficient r and its equation is shown in (2). In the candidate region, the (x_i, y_i) represents the coordinates of the center point of i-th 4-connected region. The $\bar{x}$ and $\bar{y}$ represents the average of center point (x, y) of all 4-connected regions in the candidate region. If the value of r is close to 1, the 4-connected regions will close to a straight line distribution.

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \cdot \sum_{i-1}^{n}(y_i-\bar{y})^2}} \quad (2)$$

The interval correlation coefficient k and its equation is shown in (3). The g_i is represented the distance between the i-th 4-connected region and (i+1)-th 4-connected region in the candidate region. The $\bar{g}$ represents the average interval distance of all 4-connected regions in the candidate region. The larger value of k means the distribution of 4-connected regions is uneven.

$$k = \sum_{i=1}^{n} \frac{|g_i - \bar{g}|}{\bar{g}} \quad (3)$$

The average interval width ratio t and its equation is shown in (4). The $\bar{f}$ represents the average width of all 4-connected regions in the candidate region.

$$u = \frac{\bar{g}}{\bar{f}} \quad (4)$$

The region selection is based on the feature of Thai private car license plate. The tilted angle a is between -30 to 30 degrees. The interval correlation coefficient k is between 1.5 to 5. The interval width ratio u is between 1.65 to 0.61. The length-width ratio p is between 3 to 6. Through the above conditions to filter out some candidate regions which do not satisfy the condition. In the remaining candidate regions, select a region which has the maximum linear correlation coefficient as the license plate area. The result of region selection is shown in Fig.8 (a). The final result of license plate extraction is shown in Fig.8 (b).

(a) The final region selection (b) License plate extraction

Figure 8. Final result of license plate location.

V. CHARACTER SEGMENTATION

In order to recognize characters from the image of the license plate, these characters must be separated to the isolate character from the whole license plate. The quality of segmentation also directly affects the outcome of character recognition.

The image of license plate area is obtained by the phase of license plate location is shown in Fig.9 (a). Because of The different proportion of license plates on the original image, the cropped area of the image is not the same. Hence the image preprocessing resize the image for normalization. The image of license plate area binarization is processed by MSER is shown in Fig.10 (b). And then through the fitting line angle (the tilted angle a) is used for tilted correction. In order to remove noise and reduce the interference region, the binary image undergoes the ERODED operation before the region selection.

(a) The extracted license plate (b) Binary image by MSER

Figure 9. The license plate area.

All 4-connected regions in the license plate image are marked and shown in Fig.10. The selected regions are bounded by rectangles. According to the license plate characters in length, width, length-width ratio and area, remove the region which does not satisfy the feature of license plate character. After that, the remaining 4-connected regions are taken out one by one as individual images. Each region will be regarded as an isolated character.

Figure 10. Character region selection.

According to the features of Thai private car license plate, the license plate characters can be effectively divided into Thai characters and numbers. The result of character segmentation is shown in Fig.11.

Figure 11. Character segmentation.

VI. Character Recognition

A. Thai character

Thai characters are similar in their structure. The example of similar characters come from real license plate is divided into 10x10 blocks and are shown in Fig.12. The different between 'ก' and 'ถ' is about 5 x 5 blocks in the left-down. In this situation, the optical character recognition of BPNN with pixel value cannot be shown in the high accuracy. Therefore, the feature extraction must be based on a technique which is very sensitive to the deformation of images. The feature extracted technique is described below in section B.

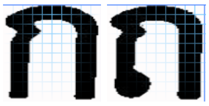


Figure 12. The Thai similar character.

B. Zernike moment

Zernike moments are image function *f*(*x*, *y*) projected on orthogonal polynomials $\{V_{nm}(x,y)\}$, Where $\{V_{nm}(x,y)\}$ is orthogonal in the unit circle and its equation is shown below:

$$V_{nm}(x,y) = V_{nm}(\rho,\theta) = R_{nm}e^{jm\theta} \qquad (5)$$

In the equation (5), *n* is a positive integer or 0, *m* is a positive or negative integer. The *n* and *m* must satisfy $n-|m|$ and it is an even number and $|m| \leq n$. The ρ is length of vector from the origin to (x,y), $\rho = \sqrt{x^2+y^2}$ (x>-1,y<1). The θ is the angle between vector ρ and X-axis, $\theta = arctan\left(\frac{y}{x}\right)$ (x>-1,y<1). The $R_{nm}(\rho)$ is radial polynomial [11] and its equation is shown below:

$$R_{nm}(\rho) = \sum_{s=0}^{n-|m|/2}(-1)^s \cdot \frac{[(n-s)!]\rho^{n-2s}}{s!\left(\frac{n+|m|}{2}-s\right)!\left(\frac{n-|m|}{2}-s\right)!} \qquad (6)$$

The Zernike moment of order *n* with repetition *m* is defined as below:

$$A_{nm} = \frac{n+1}{\pi}\iint_{x^2+y^2\leq 1} f(x,y)\, V_{nm}^*(\rho,\theta)dxdy \quad , \qquad (7)$$

where the * is a taking conjugated.

For the digital image, the integrals are replaced from (7) by summations and is given as:

$$A_{nm} = \frac{n+1}{\pi}\sum_x\sum_y f(x,y)V_{nm}^*(\rho,\theta)\ , x^2+y^2 \leq 1 \qquad (8)$$

To compute the Zernike moments of the image, the center of the image is taken as the origin and pixel coordinates are mapped to the range of a unit circle. Those pixels which are falling outside the unit circle are not used in the computation.

The Zernike moments are complex moments. The modulus value of Zernike Moments as a feature to describe the object shape. The shape features of a target object can be represented by a set of small Zernike moments feature vectors. The advantage of Zernike moments is simple rotation invariance and high accuracy for detailed shapes.

C. Character normalization

The different kinds of isolate characters in the license plate are different sizes of an image. Hence, before the characters send into the neural network, the isolated character images need to be resized for the normalization. According to the principle of feature extraction of Zernike moment, each image of the character is resized to 40 × 40. Then use the square diagonal as a diameter and the square center to make a circle. To ensure that all the pixels of the isolated character images fall inside the circle. Finally, using the diameter and the center to generate a new square is shown in Fig.13, the expended area is filled with black pixels. The purpose of normalization is to extract the features of all valid pixels by Zernike moment. These extracted feature vectors will be used for the BPNN training and recognizing.

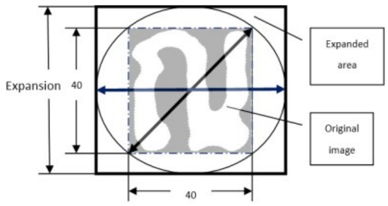


Figure 13. The character image normalization.

D. Back-Propagation neural network

In this paper, the Back-Propagation Neural Network (BPNN) is used with the sigmoid function [12]. The log-sigmoid transfer function of the BPNN is shown below:

$$f(x) = \frac{1}{1+e^{-x}} \qquad (9)$$

The Thai personal car license plate consists of the Thai characters and numbers. In the phase of character segmentation, the Thai characters and numbers are divided into two parts is shown in Fig.11. In order to increase the accuracy of character recognition, the Thai characters are sent into a Thai BPNN and the numbers are sent to numeric BPNN.

The BPNN is a multi-layer neural network. The structure of Thai BPNN is shown in Fig.14. There are four layers in the Thai and the numeric BPNN. For both of the Thai and numeric BPNN, the number of neurons in input layer are decided by the number of feature vectors that are extracted by Zernike moment. In this paper, the Zernike moment extracts 91 feature vectors for each Thai character and numbers. Select the number of neurons in the hidden layer is determined by the experimental results. The Thai BPNN chooses 16 and 15 for the number of neurons in first hidden layer and second hidden layer. The numeric BPNN chooses the 12 and 21 for the number of neurons in first hidden layer and second hidden layer. The number of neurons in output layer is decided by the number of kinds of characters. There are 44 consonant letters in Thai alphabet. However, each kind of the Thai alphabet letter in the license plate can be represented by a 6-bit binary numbers. Hence, the number of output neurons of Thai BPNN are 6. But the log-sigmoid function cannot achieve the perfect zero or one. Considering the neural network training error E_r, if the output of BPNN is greater than or equal to 0.999-E_r, it will be treated as 1. If the output of BPNN is less than or equal to $0.001+E_r$, it will be treated as 0. The example of character recognition is shown in Fig.14. The left binary image is a Thai alphabet letter which is cropped from the license plate image. After the Thai BPNN to recognize. The result of character recognition is shown in the right of image with its 6-bit binary number. On the same principle, the numbers of license plate is 0 to 9. Therefore, the number of output neurons of numeric BPNN are 4.

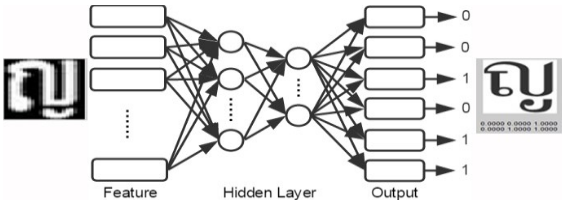


Figure 14. The structure of Thai BPNN

VII. EVLUATION OF RESULT

In this paper, the license plate images are taken from Thai private cars with High-Resolution (HR) format. These images are taken at various angles in natural light. Each image contains a different complex background. The proportion of the license plate area is between 1% to 10% of the total image space. The tilted angle of license plate is between -30 to 30 degrees. According to the actual results of license plate image collection, there are 38 kinds of Thai characters and the decimal numbers are trained and recognized by BPNN. A total of 1200 Thai license plate images are used in this experiment. The experiment uses 70% of image set (840 images) as the training set of BPNN. The remaining 30% of image set (360 images) is used to evaluate the performance of VLPR system.

TABLE I. ACCURACY COMPARING

Procedure	Proposed method	MSER+ method[5]	Essential-elements [6]	ELM method[10]
Location	95.6%	83.3%	--	--
Segmentation	98.5%	--	--	84.48%
Recognition	93.2%	--	88.24%	--

The experimental result is shown in first column of Table I. The license plate location gets the 344 correct location in 360 car images. The accuracy of the location is 95.6%. In the images which are located correctly, the character segmentation gets the 339 correct segmentation in 344 license plate areas. The accuracy of the segmentation is 98.5%. Finally, the character recognition is based on the 339 correct images of segmentation. There 316 images are total correct. The accuracy is 93.2%. In accuracy, relative to the previous methods, the improvement of this method are shown as Table I.

VIII. CONCLUSION

This paper has proposed a novel method for extraction and recognition of license plate from the image of a Thai vehicle. The license plate location in the vehicle image is close to an unconstrained location as per the MSER algorithm. The BPNN is trained with feature data of characters which is from the Zernike moment. Because of the Zernike moment is very sensitive to the deformation of image. The BPNNs effectively solve the similarity of Thai characters in the license plate. The obtained experimental results indicate that the proposed method is an efficient one for the character extraction and recognition of a license plate. In the future work, the multiple classifications which are used in this research can be replaced by other classification methods to improve the license plate extraction accuracy rate, such as k-nearest neighbors, support vector machines, etc. And also the proposed algorithm needs to undergo more research to solve the similarity problem of the Thai characters.

REFERENCES

[1] B. Li, B. Tian, Q. Yao, K. Wang, "A Vehicle License Plate Recognition System Based on Analysis of Maximally Stable Extremal Regions," ICNSC International Conference, Beijing, China, pp. 399-404, April 2012.

[2] J. Matas, O. Chum, M. Urban, T. Pajdla, "Robust wide-baseline stereo from maximally stable extremal regions," Image and Vision Computing, vol. 22, pp. 761-767, September 2004.

[3] J. Matas, K. Zimmermann, "Unconstrained Licence Plate and Text Localization and Recognition," Intelligent Transportation Systems, Proceedings. 2005 IEEE, pp. 225-230,September 2005.

[4] M. Donoser, H. Bischof, "Efficient Maximally Stable Extremal Region (MSER) Tracking," Computer Vision and Pattern Recognition, 2006 IEEE Computer Society Conference, vol. 1, pp. 553-560, June 2006.

[5] W. Wang, Q. Jiang, X. Zhou, W. Wan, "Car License Plate Detection Based on MSER," CCENet International Conference, XianNing China, pp. 3973-3976, April 2011.

[6] P. Sa-ngamuang, C. Thamnittasana, T. Kondo, "Thai Car License Plate Recognition Using Essential-Elements-Based Method," Asia-Pacific Conference, Bangkok, Thailand, pp. 41-44, October 2007.

[7] R. Juntanasub, N. Sureerattanan, "Car License Plate Recognition through Hausdorff Distance Technique," ICTAI 17th IEEE International Conference, Hong Kong, November 2005.

[8] A. Leelasantitham, S. Kiattisin, "A Position-Varied Plate Utilized for A Thai License Plate Recognition," SICE Annual Conference, SICE Annual Conference 2010, Chinese Taipei, pp. 3303-3307, August 2010.

[9] C. Pornpanomchai, N. Anawatmongkon, "Thai License Plate Recognition System From a Video Stream," Silpakorn U Science & Tech J, vol. 8, No.2, 2014.

[10] S. Subhadhira, U. Juithonglang, "License Plate Recognition Application Using Extreme Learning Machines," Third ICT International Student Project Conference (ICT-ISPC2014), Nakhon Pathom, Thailand, pp. 103-106, March 2014 .

[11] A. Tahmasbi, F. Saki, H. Aghapanah, S. B. Shokouhi, "A Novel Breast Mass Diagnosis System based on Zernike Moments as Shape and Density Descriptors," in Proc. IEEE, 18th Iranian Conf. on Biomedical Engineering (ICBME'2011), pp. 100-104,Tehran, Iran, December 2011.

[12] S. Russell, P. Norvig, Artificial Intelligence: A Modern Approach, 2nd ed, Pretice Hall, 2002, pp.736-748.