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

By
Mr. Tao Horng

Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Computer Science Assumption University

March 2015
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Vincent Mary School of Science and Technology

Master Thesis Approval

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Academic Year: 2/2014

The Department of Computer Science, Vincent Mary School of Science and Technology of Assumption University has approved this final report of the twelve credits course, SC7000 Master Thesis, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer Science.

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ACKNOWLEDGEMENTS

The writer desires to express his most sincere appreciation and thanks to Dr. Anilkumar K.G for his encouragement and advice through the course of this study and for his help in the preparation and writing of this research.
ABSTRACT

This research aims to present and discuss the vehicle license plate recognition of Thai vehicle license plates based on MSER (Maximally Stable Extremal Region) and BPNN (Back-Propagation Neural Network). License plate recognition technology is the core technology of intelligent transportation systems. With the development of computer vision and digital image processing capabilities, license plate recognition has been widely used now. 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.
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CHAPTER 1: INTRODUCTION

With rapid economic development and urban expansion, and transportation volume increase 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, highway management, parking management system, vehicle location and navigation, traffic surveillance 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) combine with Zernike moment.

1
The rest of the paper is organized as follows. Chapter 2 briefly describes literature review in the related work. The structure of VLPR system is introduced in Chapter 3. The detail of license plate location is presented in Chapter 4. Chapter 5 explains the character segmentation and classification. The character recognition steps are presented in Chapter 6. In Chapter 7, the experimental results from the VLPR system are showed with different condition. Chapter 8 explains the evaluation of the experimental results and performance of VLPR system. Finally, the conclusion and future works are in Chapter 9.
CHAPTER 2: LITERATURE REVIEW

From the literature review, it is mentioned that a lot of license plate location methods are 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]. A Thai license plate recognition system using Extreme Learning Machine (ELM) [10]. 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.
CHAPTER 3: SYSTEM OVERVIEW

The structure of the vehicle license plate recognition system is shown in Figure 3-1. 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 changed 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 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.
CHAPTER 4: LICENSE PLATE LOCATION

4.1 OBJECTIVE 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 black font in red background, the taxi license plate is black font in yellow background, etc. This paper focuses on Thai private car license plate with a complex background as shown in Figure 4-1. The private car license plates are indicated with black font in white background.

![License plate image](image)

Figure 4-1 License plate image.

In the complex background, the presence of asymmetrical illumination, shadow, billboards and artificial structures make the interference area increase. Too much interference regions lead to increase in the amount of calculations. This factor increases the difficulty of the license plate localization. In order to effectively extract the license plate area from a car image with complex background, 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 "1M 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 Figure 4-2. Some edges are covered by the frame, therefore the size of license plate reduces to 12.5 by 33.2 centimeters. The Thai character is about 6.5 by 4.5 centimeters and the number is about 6.5 by 3.7 centimeters in size. Depending on the different characters, the size of a character in the license plate will be changed.

![License plate structure](image)

**Figure 4-2 License plate structure.**

### 4.2 MAXIMALLY STABLE EXTREMAL REGIONS

In computer vision, the maximally stable extremal regions are used as a method of blob detection in images. The concept of maximally stable extremal regions 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 \( Q_1, ..., Q_{l-1}, Q_l \) be a sequence of nested extremal regions \((Q_i \subset Q_{i+1})\). The extremal regions \( Q_i \) is maximally stable if and only if the equation (1) has a local minimum.

\[
q(i) = \frac{|Q_{i+\Delta} \setminus Q_{i-\Delta}|}{|Q_i|}
\]

The symbol \( \Delta \) 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) Stability. 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 Figure 4-3. 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 4-3 Maximally stable extremal regions.](image)

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

![Figure 4-4 Two types of MSERs.](image)
4.3 IMAGE PREPROCESSING

The images of 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 ensure the undistorted images, but also keep 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 the increase in 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.

Figure 4-5 MSER mixed image.
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 Figure 4-5.

![Figure 4-5](image)

**Figure 4-5 After elimination.**

In order to eliminate some part of the interference region and reduce the unnecessary amount of computation, each MSER is marked by 4-connected regions. Every regions are calculated length, width, length-width ratio and area. The elimination is based on the prior knowledge of Thai private car license plate. If the region does not satisfy the features of characters in the license plate, it will be eliminated. For example, the length of region is not larger than its width, the length-width ratio of 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 Figure 4-6.

![Figure 4-6](image)
4.4 MULTIPLE CLASSIFICATION

First of all, the horizontal classification is according to the characteristics of normal capturing of the license plate images as shown in Figure 4-1. 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 use up-line and down-line to separate no pixels areas with the pixels area as shown in Figure 4-7. 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 large 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 spacing 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 Figure 4-8.

The linear classification is based on the result of the horizontal and vertical classification. In normal circumstances, the distribution of the center point of license plate characters is close to a straight line. But because of the special nature of Thai characters, 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 Figure 4-9. After that, the distance is calculated 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.

Figure 4-10 Height classification.

The height classification is based on the result of the 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, the average height of each class is calculated. 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 Figure 4-10.
4.5 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 $\alpha$, 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 $\alpha$ 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.

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

$$k = \sum_{i=1}^{n} \frac{|g_i - \bar{g}|}{\bar{g}}$$  \hspace{1cm} (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.

\[ u = \frac{\bar{y}}{f} \]  

(4)

The region selection is based on the feature of Thai private car license plate. The tilted angle \( \alpha \) is between -30 to 30 degree. 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.

![Figure 4-11 The final region selection.](image)

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 Figure 4-11. The final result of license plate extraction is shown in Figure 4-12. The actual area and location area are different. The actual crop area expanded or reduced in a proportion which based on the real proportion of license plate. The actual cropped area is marked by the yellow rectangle.
Figure 4-12 License plate extraction.
CHAPTER 5: CHARACTER SEGMENTATION

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

Figure 5-1 The extracted license plate.

The image of the license plate area is obtained by the phase of the license plate location as shown in Figure 5-1. 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 as shown in Figure 5-2. And then through the fitting line angle (the tilted angle $\alpha$) is used for tilted correction. In order to remove noise and reduce interference region, the binary image is undergo the ERODED operation before the region selection.

Figure 5-2 Binary image by MSER.

All 4-connected regions in the license plate image are marked and shown in Figure 5-3. 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 5-3 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 Figure 5-4.

Figure 5-4 Character segmentation.
CHAPTER 6: CHARACTER RECOGNITION

6.1 THAI CHARACTER

Thai characters are similar in their structure. The example of similar characters from real license plate is divided into 10x10 blocks and are shown in Figure 6-1. The different between ‘n’ and ‘o’ 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 next section.

![Figure 6-1 The Thai similar character.](image)

6.2 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:

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

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 $\rho$ is length of vector from the origin to $(x, y)$, $\rho = \sqrt{x^2 + y^2}$ ($x > -1, y < 1$). The $\theta$ is the
angle between vector $\rho$ 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:

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

(6)

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

$$A_{nm} = \frac{n+1}{\pi} \iint_{x^2+y^2\leq1} f(x, y) V_{nm}^*(\rho, \theta) dx dy$$  

(7)

where the $*$ is a taking conjugated.

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

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

(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 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 that feature vectors. The advantage of Zernike moments is simple rotation invariance and high accuracy of detailed shapes.

6.3 CHARACTER NORMALIZATION

The different kinds of isolate character in license plates are different sizes of an image. Hence, before the characters are sent 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 $40 \times$
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 Figure 6-2, 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 6-2 The character image normalization.](image)

6.4 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:

\[
f(x) = \frac{1}{1+e^{-x}}
\]

(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 as shown in Figure 5-4. 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 Figure 6-3. 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 is 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 the 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 Thai characters is encoding by six bit binary numbers. For each Thai character corresponds to a code is shown in Table 6-1. The binary number is from 000000 to 101010. Therefore, it represents the 44 Thai characters in the BPNN output.

**Table 6-1 Thai character encoding.**

<table>
<thead>
<tr>
<th>code</th>
<th>character</th>
<th>code</th>
<th>character</th>
</tr>
</thead>
<tbody>
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<td>0 0 0 0 0 1</td>
<td>ก</td>
<td>0 1 0 1 1 0</td>
<td>อ</td>
</tr>
<tr>
<td>0 0 0 0 1 0</td>
<td>ป</td>
<td>0 1 0 1 1 1</td>
<td>บ</td>
</tr>
<tr>
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<td>ภ</td>
<td>0 1 1 0 0 0</td>
<td>บ</td>
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<td>ง</td>
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The example of character recognition is shown in Figure 6-4. The left binary image is a Thai alphabet letter which is cropped from the license plate image. It is fed into the Thai BPNN to recognize. The result of character recognition is shown in right image with its 6-bit binary number. In the same principle, the numbers of license plate is 0 to 9. Therefore, the number of output neurons of numeric BPNN are 4.

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<th>code</th>
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<td>0 1 0 0 0 0</td>
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</table>

Figure 6-4 The result of character recognition.
CHAPTER 7: EXPERIMENTAL RESULT

7.1 LICENSE PLATE EXTRACTION RESULTS

The result of license plate extraction is shown in figure 7-1 and 7-2. In this experiment, the license plate is start from 1% to 10% area in the total space of the image. Figure 7-1 is the small area license plate (about 1%) in the vehicle image. The figure 7-
2 is the larger area license plate (about 10%) in the vehicle image. The red line box is the initial extraction area. The yellow line box is fix cropped area. the license plate area extraction is shown in the image by an enlarged form.

7.2 CHARACTER SEGMENTATION RESULT

The positioning of characters

![Separated characters](image)

Figure 7-3 The old version of the license plate.

The positioning of characters

![Separated characters](image)

Figure 7-4 The new version of the license plate.

The method of character segmentation is suitable for the old and the new type of private car license plate. The result of old version of the license plate segmentation is shown in figure 7-3. The result of new version of the license plate is show in figure 7-
4. In the figure, the tilt corrected license plate is shown in the top of image with black and white color. The isolate character is divided into Thai and number.

7.3 CHARACTER RECOGNITION RESULT

![Figure 7-5 Character recognition result.](image)
The character recognition result is shown in figure 7-6. The original plate is shown in the top of image. The isolate character is used to recognize by BPNN. The result is shown in the bottom of the image.

7.4 LICENSE PLATE RECOGNITION SYSTEM

![Image of license plate recognition system]

Figure 7-6 License plate recognition system.

The license plate recognition system is shown in figure 7-7. The system contains the license plate extraction, character segmentation and character recognition. In this experiment, the system is used to evaluate the method which is mentioned above.
CHAPTER 8: EVALUATION 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 7-1 Accuracy comparing.

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<td>Location</td>
<td>95.6%</td>
<td>83.3%</td>
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<tr>
<td>Segmentation</td>
<td>98.5%</td>
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<td>--</td>
<td>84.48%</td>
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<tr>
<td>Recognition</td>
<td>93.2%</td>
<td>--</td>
<td>88.24%</td>
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</table>

The experimental result is shown in second column of Table 7-1. 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 are 316 images that totally correct. The accuracy is 93.2%. In accuracy, relative to the previous methods, the improvement of this method are shown in Table 7-1.
CHAPTER 9: 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 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 works, 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. Because of the property of Zernike moment, the number ‘6’ and ‘9’ are difficult to be distinguished. This problem will also have to be improved. The accuracy of the entire VLPR system is 88%. Therefore, this system also needs to be improved before it applied in a real system.
References


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

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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.

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
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.

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 "1n1234", 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.

### 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.

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.
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).

\[
k = \frac{\sum_{i=1}^{n} |y_i - \bar{y}|}{\bar{y}}
\]

(3)

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

\[
u = \frac{\bar{w}}{f}
\]

(4)

The region selection is based on the feature of Thai private car license plate. The tilted angle \( \alpha \) 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 2 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).

**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 \( \alpha \), 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 \( \alpha \) 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 \( x \) and \( y \) represents the average of center point \((x, y)\) of all 4-connected regions in the candidate region. If the value of \( r \) close to 1, the 4-connected regions will close to a straight line distribution.

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

(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.

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 \( \alpha \)) is used for tilted correction. In order to remove noise and reduce the interference region, the binary image undergoes the ERODE operation before the region selection.

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 by one as individual images. Each region will be regarded as an isolated character.

![Character region selection.](image)

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.

![Character segmentation.](image)

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 'n' and 'm' 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.

![The Thai similar character.](image)

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:

\[
V_{nm}(x, y) = V_{nm}(\rho, \theta) = R_{nm}e^{im\theta}
\]  

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

\[
R_{nm}(\rho) = \sum_{m=0}^{n-|m|/2} (-1)^{m} \frac{(n-|m|)!}{|m|!(n-|m|+2m)!} \rho^{n+2m} \frac{(n+2m)!}{(2|m|)!} (\frac{\rho^2}{2|m|^2} - \frac{1}{2})
\]  

(6)

The Zernike moment of order \( n \) with repetition \( m \) is defined as below:

\[
A_{nm} = \frac{n+1}{\pi} \sum_{x=1}^{x_{max}} \sum_{y=1}^{y_{max}} \sum_{s=0}^{s_{max}} f(x, y) V_{nm}(\rho, \theta) \rho d\rho d\theta
\]  

(7)

where \( * \) is a taking conjugated.

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

\[
A_{nm} = \frac{n+1}{\pi} \sum_{x_{max}} \sum_{y_{max}} f(x, y) V_{nm}(\rho, \theta), x^2 + y^2 \leq 1
\]  

(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 x 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.

![Character image normalization.](image)

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:

\[
f(x) = \frac{1}{1 + e^{-x}}
\]  

(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 16-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 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](image)

### VII. EVALUATION 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.

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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 unknown trained location. The proposed method 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


