Vehicle License Plate Recognition Based on Text-line Construction and Multilevel RBF Neural Network

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***Abstract*—License plate localization and character segmentation and recognition are the research hotspots of vehicle license plate recognition (VLPR) technology. A new method to VLPR is presented in this paper. In license plate localization section, Otsu binarization is operated to get the plate-candidates regions, and a text-line is constructed from the candidate regions. According to the text-line construction result and the characteristics of the license plate character arrangement, the license plate location will be determined. And then the locally optimal adaptive binarization is utilized to make more accurate license plate localization. After the license plate localization, the segment method of vertical projection information with prior knowledge is used to slit characters and the statistical features are extracted. Then the multilevel classification RBF neural network is used to recognize characters using the feature vector as input. The results show that this method can recognize characters precisely and improve the ability of license plate character recognition effectively.**

***Index Terms*— License plate localization, License plate character recognition, Text-line construction, Multilevel classification RBF neural network**

I. INTRODUCTION

The vehicle license plate recognition (LPR) technology has important application in Intelligent Transportation Systems (ITS) and has been used extensively in highway and bridge charge, port, airport gate monitoring, and so on. It is conceptually considered that the two key separate processing stages of license plate recognition are license plate localization (LPL) and License Plate Character Recognition (LPCR) 0. Normally the license plate recognition system is running outdoors, and the images are easily interference because of complex background and a wide range of illumination conditions. The hot problems are how to localize the license plate and segment character in the license plate from images of different backgrounds and illumination conditions precisely, reliably and fleetly. At present, some scholars have done a lot of researches on these problems and promoted the development of this domain [2][3][4].

License plate localization, including the algorithms to detect the rectangular area of the license plate in an original image, is the most crucial and difficult processing stage. The success and accuracy of the localization will directly determine the post recognition and identification accuracy. Several of undesired conditions of input image, such as image blur, undesired illumination, rotation, vehicle model and small size license plate will influence the localization result. Hsieh [5] and B. Hong-liang [6] proposed morphological filtering method to localize the license plate. This method is fail to localization in complex images with small license plate because there might be a number of undesired features. Approaches of license plate localization based on edge detection, gradient and other variants of intensity derivatives [7][8][9] are sensitive to noise and illumination variation. Sliding windows (SW), a method based on image segmentation technique, is also proposed for detecting candidate license plate region. In license plate segmentation the irregularities in the texture and abrupt changes in the local features of the image usually manifest the presence of a license plate [11]. The main drawback of this method is the excessively time-consuming computation. A modified color texture-based method for localizing license plate in images is presented in [12]. A support vector machine (SVM) is used to analyze the color and texture properties of license plates, and is also used to locate their bounding boxes by using a continuous adaptive mean shift algorithm (CAM Shift). However this method is also time-consuming.

At present there are many kinds of algorithms of license plate character recognition [13][14]. The typical method is based on pattern matching [15]. However, the pattern matching is sensitive to expansive, inclined images and disturbed background. There are several other mature algorithms such as statistical pattern recognition, artificial neural network method, etc. Artificial neural network method has many advantages [16]. It has parallel processing ability, high adaptability, good study ability, strong association function and fault tolerance function. So it has high recognition rate, strong anti-disturbance ability and flexibility, but the study process needs a long time. In the reference [15], the one-dimension vertical projection is used to slit characters of pre-processing images, and then the statistical features are extracted. The feature vector is the input of the RBF neural network. The RBF neural network is applied to recognize the characters, which effectively improves the ability of

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license plate character recognition. Wisam[17] develops fuzzy rules to recognize the segmented characters and numbers. This method is only suitable to the standard size license plates. Regarding the non-standard size license plates, the method is not effective.

In this paper, a method based text-line construction and RBF neural network is proposed for license plate recognition. The flowchart of the method is illustrated in Fig.1. Firstly, the candidate license plate region is detected by using Otsu method. Secondly, the background noise is filtered and the text-line is constructed to verify the candidates. Thirdly, locally optimal adaptive binarization is utilized to complete the license plate localization. Fourthly, the characters in the license plate region are segmented. Lastly, the character features are extracted and the characters are recognized by using multilevel classification RBF neural network.

II. License plate localization

A. Binarization

Generally, license plate area is often with high contrast. Therefore, the foregrounds and backgrounds can be separated by binarization method. Considering the inherent nature of vehicle images, we propose a two-stage binarization mechanism in this study.

In the first stage, detect license plate candidates using Otsu method [19]. The license plate candidates may contain noises and incorrectly selected regions so that they could be considered to be license plate by mistakes. Character filtering and text-line construction were operated to verify the candidates. The second stage binarization will be operated after the text-line construction. After the text-line construction, the incorrect candidates will be removed, only the license plate region is preserved. In the second binarization stage, the preserved license plate region will be divided into several regions according to the features of the license plate, and each region will be binarized by locally optimal adaptive binarization[18].

B. Text-line construction

In this section, text-line construction is adopted to verify the location of the license plate. There might be several candidates regions after the first stage binarization and character filtering, but only the candidates region that can construct the text-line can be preserved to be the license plate region.

In China, the standard license plate consists of 7 characters, of which the first is the Chinese character, the second is capital letter, third and fourth may be a capital letter, or a number, the fifth, sixth and seventh are currently digital[20]. Only the 65 characters shown in Table I can be used in the license plate. Fig.3 shows the standard license plate. All the 7 characters have the same full typo-classes, one class of the typographical structure [21]. The center distance of every two adjacent characters or letters in the region before the gap symbol or after the gap symbol is equal. The distance is proportional to the height of the character or letter.

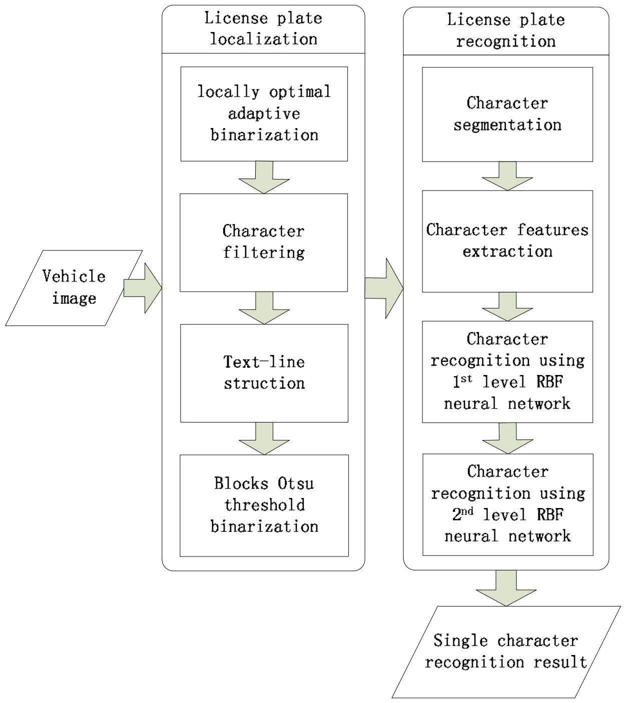


Figure 1. The flowchart of proposed method

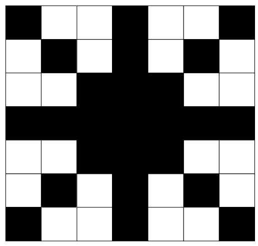


Figure 2. The 7×7 mask of auto-regressive feature

Considering the features of the plate characters and the practical factors, such as noise, perspective and illumination, the following criterions to text-line construction were proposed:

1) There are only 7 connected components included in a text-line.

Considering the license plate shown in Fig.3, there are only 7 characters in a standard license plate. Therefore, in a license plate text-line, only 7 connected components included. However, the Chinese characters are made up of several separated parts, which means a Chinese character will be made up of several connected components. Therefore, we construct the 6 non-Chinese characters firstly, and add the Chinese character connected components at the last.

2) The angle θ_{ij} should not be greater than 10°.

θ_{ij} is the intersection angle between the horizontal line and the attachment of the two connected component centers. Usually, the shooting angle is fixed in the Intelligent Transportation Systems, and the license plate incline angle does not exceed 10°.

TABLE I. CHARACTERS IN LICENSE PLATE

京	津	冀	晋	蒙	辽	吉	黑
沪	苏	浙	皖	闽	赣	鲁	豫
鄂	湘	粤	桂	琼	渝	川	贵
云	藏	陕	甘	青	宁	新	0
1	2	3	4	5	6	7	8
9	A	B	C	D	E	F	G
H	J	K	L	M	N	P	Q
R	S	T	U	V	W	X	Y
Z							

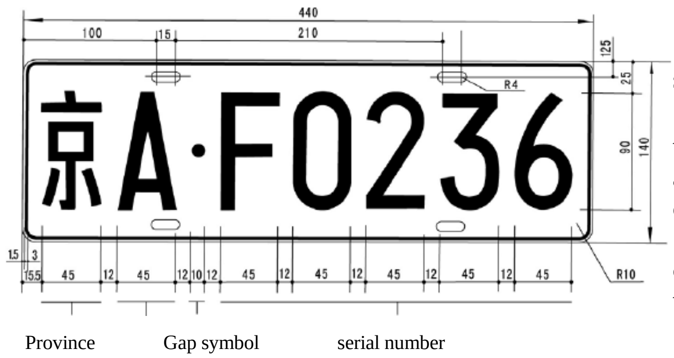


Figure 3. License plate style

3) The center distance (see Fig.4) of every two connected component before or after the gap symbol is equal, and the distance is proportional to the height of the connected component.

The two connected components, whose center distance satisfying the following inequality, can be preserved to be the license plate:

$$0.65 \le \frac{D_{ij}}{H_{ij}} \le 0.90 \quad (1)$$

$$H_{ij} = \frac{H_i + H_j}{2} \quad (2)$$

Represent the two connected components by CC_i and CC_j. D_{ij} is the center distance of the two adjacent connected components CC_i and CC_j. H_i and H_j are the height of the connected components. H_{ij} is their arithmetic mean.

The text-line construction is operated as following steps:

Step 1. For an unvisited plate-candidate area CC_i and its neighboring CC_j, angle θ_{ij} is the angle between CC_i and CC_j should not exceed 10° .

If the θ_{ij} satisfies the request above, go to Step 2. Otherwise, select another neighboring CC_k with the second center distance and check the angle θ_{ik}. If the angle θ_{ik} satisfies, go to Step 4. If both angle θ_{ij} and angle θ_{ik} exceed the angle limit, go to Step 6.

Step 2. Check the D_{ij} using the Eq. (1) and Eq. (2). If the inequality in Eq. (1) is satisfied for D_{ij}, go to Step 3. Otherwise, go to Step 6.

Step 3. Link CC_j to CC_i. Go to Step 1 and repeat the steps to check the next plate- candidate area CC_j.

Step 4. Check the D_{ik} using the (1) and (2). If the inequality in (1) is satisfied for D_{ik}, go to Step 5. Otherwise, go to Step 6.

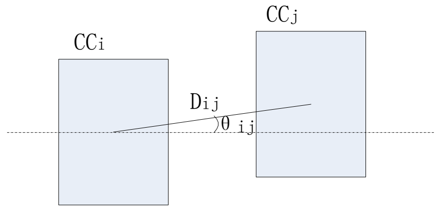


Figure 4. Illustration of the center distance of two connected components

Step 5. Link CC_k to CC_i. Go to Step 1 and repeat the steps to check the next plate- candidate area CC_j.

Step 6. CC_i cannot be connected with any other CC at this stage. Find another unvisited CC_j and go to Step 1. If all connected components have been visited, terminate the operation.

After performing the above construction steps, the 7 connected components of the license plate will be linked to a text-line.

III. LICENSE PLATE CHARACTER SEGMENTATION

To recognize the Chinese characters, letters and numbers, a single character must be extracted from vehicle plates. The segmentation results directly affect character recognition. The license plate image is binarized before separation, then row scanning method based on prior knowledge is applied to process the frame and rivet. In this article the segment method of vertical projection information with prior knowledge is developed, and is modified to improve the precision.

Before the recognition, the seven characters must be separated out from the plate in the picture. If the total gray values of every column pixels are calculated based on binary images, the vertical projection can be acquired. The chart of vertical projection is shown in Fig.5.

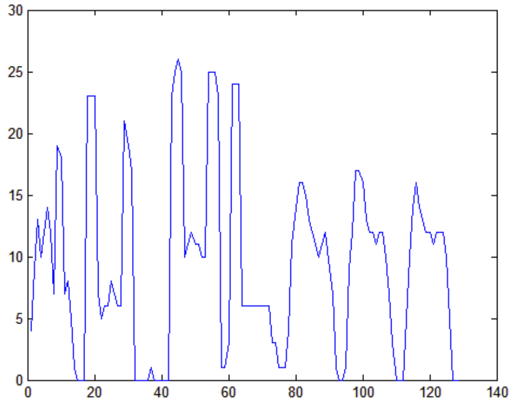
In Fig.5 the X axis is column of vehicle plate images, and the Y axis is the projection value. The figure shows that the vertical projection of plate has 7 groups of regular comb chart. There is a fixed space size between groups, except the space between the 2nd and 3rd is bigger. Significantly every comb chart stands for one character, and the space between groups corresponds to the space between characters. In vertical projection of binary images as long as the space position is found, the every character position is determined. One of the important conditions to judge space is that the projection value is 0 in space position.

The size of standard vehicle license plate character is $45 \times 90\,mm$, character spacing is $12\,mm$, character spacing between the 2nd and 3rd is $34\,mm$, and the total width of the 7 characters is $409\,mm$. Using these prior knowledge, the character size of factual plate image can be calculated, where W is the total width.

The character width:

cl (3)

(a) The license plate image



(b) The vertical projection of the license plate image

Figure 5. The vertical projection of license plate

The usual space between characters:

(4)

The space between the 2nd and 3rd:

s (5)

So the start position to search ($spos$) can be calculated as follows:

$$spos = cWidith \times 2 + space + \frac{1}{2}s \tag{6}$$

To make the character segmentation algorithm practical, several questions must be solved such as the images in case of adhesion, deviation of right or left and disturbance by minor noise.

1) The character width and space can be calculated by (3) ~ (5) . It can solve the segmentation of adhesion character using prior knowledge.

For example, segment characters by the way of searching to right, the idea is as follows:

First search the start position sC and end position eC of character n (n =2,3, ······)

Then judge whether the $(eC \quad sC)$ value is more than cWidth;

If $(eC - sC) \leq cWidth$, that means there is no adhesion in character n;

If $(eC - sC) > cWidth$, that means n is adhesion character. It must be segmented compulsory. So-called compulsory segmentation, it means that let sC be the left bound of character n , that is to say $cpos[n]left = sC + cWidth$.

Then the right bound is $sC + cWidth$, left bound of character $n+1$ is $cpos[n]right = cpos[n]right + space$, that is $cpos[n+1]left = cpos[n]right + space$. Last let be $sC = cpos[n]left$, back to the 2nd step to judge $(eC - sC)$again until it fits to the standard width.

2) To avoid the left and right deviation, it is necessary to define the actual plate width. In another word, to search the plate's left and right bound in binary images.

By the use of vertical projection, search from left to right until find the column j that the vertical projection P_j^- is more than a certain threshold T (T is empirical value), and make it as start column sC; then, search from right to left until find the column j that the vertical projection P_j^- is more than threshold T, and make it as the end column eC. Last calculate the license plate width by $W = eC - sC$ again. Now substitute the afresh plate width into(3) ~ (5) to solve the character segmentation failure because of left and right deviation.

3) The minor noise includes the disturbance of points between the 2nd and 3rd character and other glitch as well.

In character segmentation algorithm use the condition of $P_k \neq 0$ to judge character position. We can set a noise threshold of fault tolerance $noiseThd$, and change judgment condition to $P_j > noiseThd$. Meanwhile verify the characters whose position has been determined, and judge whether the width W meets $cWidth$. If it is satisfied, the result is character, else it is noise. It needs to segment again.

Using the method of projection and standard vehicle plate's prior knowledge to segment character and modify it, the precision is ensured. It can process some cases of vehicle plate images such as adhesion characters, plates of left and right deviation and minor noise interference.

IV. Extract Character Feature

The aim of character feature extraction is to find the most efficient feature from feature space. Therefore, how to choose an efficient feature from many features is the key to recognize character. Usually the method of coarse grid feature extracting is defined that the characters to recognize should be normalized firstly by size and position, divided into N×N grids equally, and then the number of white pixels in grids is calculated in turn to get one N × N dimension grid feature by numeric form. Because coarse grid feature belongs to local gray feature, even if it can show total shape distribution of character, but the ability of anti-disturbance of stroke position change is poor and thus the recognition rate will be decreased. What's more, the coarse grids features ignore some detail features which are very important to character classification with similar structure.

Because the vehicle plate character recognition belongs to minimal classification and this kind of image is disturbed by environmental noise inevitably, every pixel of normalized character dot matrix is applied as one grid. In another words, we extract character original feature and input them into neural network classifier to classify characters. In this method, the images are scanned row by row and column by column in the order of left to right and up to down. Then pixel gray are calculated. The statistic result is regarded as feature vector. The vector's dimension is defined as width multiplied by length. In this paper the vehicle plate character is first normalized to binary images by size of 24×15, 360 feature points are extracted by the coarse grid method, and input into neural network classifier to sort.

V. Neural Network Recognition Algorithm

A. Characteristics of neural network algorithm

Neural network is a hot research domain and its application is extensive. There are many kinds of neural network models. The radial basis function neural network (RBF) is a typical local approximation neural network and it is better than back propagation (BP) neural network in such abilities as approximation, classification and study (e.g., [22] and [23]). In this study, we used RBF as the plate character classifier because RBF is a feed-forward neural network and has simple model structure. In addition, it also contains some other self features such as optimal approximation and non-local minimum, fast convergent speed and simple topology structure.

B. Multilevel classification RBF network

Considering that 7 characters in license plate might be the fixed type, we divide the license plate into 4 sub-regions. The 1st region contains only one Chinese character, the 2nd region contains only one capital letter, the 3rd region contains 2characters which might be capital letter or number, and the 4th region only contains 3numbers. In order to satisfy the character recognition of 4 sub-regions, a multilevel classification RBF neural network is proposed [24]. The first level RBF neural network, which contains Chinese character sub-network, capital letter sub-network, mixing sub-network and number sub-network, is designed to rough classification. The second level network is designed for improve the recognition accuracy. It contains several sub-networks classifying the confusable characters, such as 2, 3 and 7.

The features of characters from the segmented images are extracted and then normalized. Taking the normalized features of the characters as the inputs of the first level classification RBF neural network is to train separately according to the sub-region they belong to. Furthermore, we select the second level network according to the first classification result, and take them as the inputs of the second level network.

C. Design of RBF neural network

1) Experiment samples choice

The experiment samples are color vehicle images including static and dynamic vehicle. The design of RBF is consisted of several steps. Firstly, the collected images are preprocessed such as graying, binary, inclination emendation and getting rid of interference. Secondly, the vertical projection method was applied to segment single character and then the extract features are normalized into 24x15 character matrixes. Furthermore, the normalized character matrixes are made as neural network input to train RBF neural network. The last step is to use the trained RBF neural network to recognize character.

The training samples are selected from the segmented characters. For every character, 5 different samples are chose and their corresponding vectors are put into RBF neural network for training, the left characters are used as test samples.

2) Determine the reference of RBF neural network

a) Determine the number of input nodes

The neutron number between input the layer and output layer is decided by problem itself. The dimension of coarse grid feature which is selected from the characters to be recognized gives the neutron number of input layer. In this vehicle plate recognition system the character is normalized by size of 24×15, so that every pixel is one grid, and the neutron number of input layer is 360.

b) Determine the number of hidden and output nodes

In k-means clustering method the initial hidden node number is equal to output node number. For our modified method, the hidden node number is always set as equal to output node number. The typical method to design neural network model classifier is to train its model samples and class label, then use the mode of "1 selected from M" to represent goal vector. So the neutron number of output layer is M which is also the class number to be recognized, where every neutron stands for a goal class. In this design, 1 represents target class and 0 stands for non-target class when using binary to train network. The mode of "1 selected from M" can be implemented to describe target vector in number network, letter network, as well as number and letter network.

c) Determine the hidden function center c_j and radius δ_j

The hidden function center c_j is determined by k-means clustering method and the modified study method. δ_j is calculated by (7):

$$\delta_j = \sqrt{\sum_{k=}^{k}} \qquad (7)$$

d) Train the connection weight value from hidden layer to output layer

Due to all the weight value is 1 from hidden to output layer, every hidden node output can be acquired after given input vector and every node function of hidden layer. Then the RBF neural network is trained using the linear least square method to obtain the connection weight values. As a result so far, RBF neural network model is established and used as classifier of vehicle plate character input later.

e) Recognize test samples

After determining the neural network model, the test samples are put into network to operate the next test.

When one character vector is input, the sort number is obtained after calculating in hidden and output layer. Comparing this sort number to the self sort one of input feature vectors, the recognition character can be obtained.

VI. Simulation Results and Analysis

In this section, experiments were performed using the proposed method. The sample images were color vehicle license plate images of different size, clarity, illumination and inclination. Two experiment procedures were given to illuminate the process as shown in Fig. 6 and Fig.7. In each figure, (a) is the original image. The gray image is shown in (b). (c) to (e) are demonstrated as the license plate localization results using the proposed method.

After the license plate localization, the vertical projection method introduced in section 3 was applied to segment character. The vertical projections are shown in (f), and the character segmentation results are shown in (g). The segmentation results demonstrated that the proposed method can effectively solve the character adhesion problem and a very accurate segmentation results can be obtained.

It is worthy to mention that before the character feature extraction, the segmented characters should be normalized to the certain size 24×15 to extract the original feature showed in Fig.8. As a example, we selected 3 character feature extraction results to illuminate the process.

Recognizing the character features is carried out by the multilevel RBF network. It is found that the input signal P is a matrix of 360×36, and target vector T is a unit diagonal matrix of 36×36. Lastly, the trained RBF neural network was used to recognize character, and the results show that the feature vectors of character to be recognized are the corresponding column vectors in target vector T. The character recognition results are shown in Table 2.

The different Chinese character, capital letter or number has their own different recognition rate. The data showed in Table 2 represent the mean recognition rates of the three kinds of characters. Due to the complex structures of Chinese characters, the Chinese character recognition rate is lower than capital letter and number recognition rate. For some confusable characters, such as 2, 7, 3, 8, B, 0 and Q, the recognition rates are relatively lower than the other characters. However, the distinctive characters, such as W, X, K, 9 and Z, have relative higher recognition rates.

VII. Conclusions

A novel method for license plate recognition is proposed in this paper. Local adaptive binarization and text-line construction are operated to localize the license plate. After the license plate localization, the method of vertical projection information with prior knowledge is proposed to segment character and extract the statistic feature. The multilevel classification RBF neural network is then used to recognize with feature vectors as input. The tested results show that the proposed method can recognize Chinese character, capital letter and number correctly and efficiently. The recognition result is reliable and satisfied by the accuracy requirement of the Intelligent Transportation Systems.

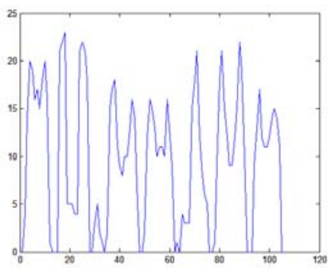
(a) Original image

(b) Gray image

(c) Otsu binarization result

(d) Text-line construction result

(e) License plate localization result



(f) Vertical projection of the license plate

(g) Characters segmentation result

Figure 6. No.1 experiment results

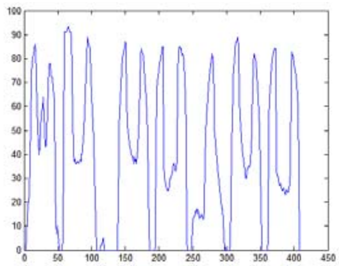
(a) Original image

(b) Gray image

(c) Otsu binarization result

(d) Text-line construction result

(e) License plate localization result



(f) Vertical projection of the license plate

(g) Characters segmentation result

Figure 7. No.2 experement results

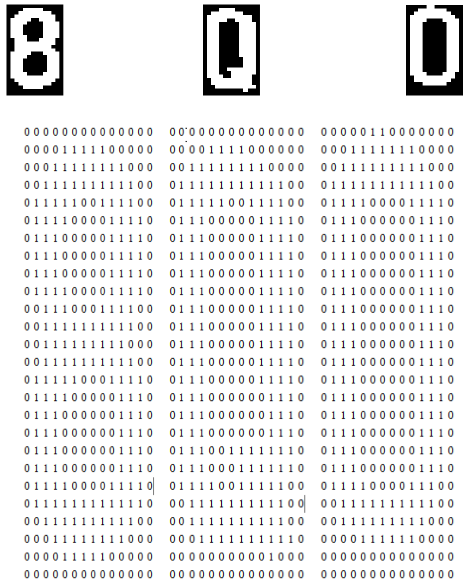


Figure 8. Feature extraction diagram

TABLE II. CHARACTER RECOGNITION RESULT

Character type	Chinese characters	Capital letters	Numbers
Number of samples	120	179	541
Recognition rate (%)	89.3	94.1	93.6

REFERENCES

[1] Vladimir Shapiro, Dimo Dimov, Stefan Bonchev, etc. “Adaptive License Plate Image Extraction,” *International Conference on Computer Systems and Technologies CompSysTech’2003*, pp.IIIA.2-1-IIIA.2-7.

[2] COMELL I P, “Optical recognition of motor vehicle license plates,” *IEEE Transactions on Vehicular Technology*, 1995, vol.44, pp. 790-799.

[3] NAITO T, “Robust license plate recognition method for passing vehicles under outside environment,” *IEEE Transactions on Vehicular Technology*, 2000, vol.49, pp. 2309-2319.

[4] Wei Huang, Xiaobo Lu, etc, “Vehicle plate location based on wavelet and texture analysis,” *Engineering Sciences*, 2004, vol.6, pp. 16-22 (in Chinese).

[5] Hsieh, J.W., Yu, S.H., Chen, Y.S., “Morphology-based License Plate Detection from Complex Scenes,” *International Conference on Pattern Recognition*, Quebec City, CA, 2002, vol.3, pp. 176-179.

[6] B. Hong-liang and L. Chang-ping, “A hybrid license plate extraction method based on edge statistics and morphology,” *17th International Conference on Pattern Recognition* (ICPR’04), 2004, vol 2, pp.831–834.

[7] Kim,S., et al., “A Robust License-Plate Extraction Method under Complex Image Conditions,” *International Conference on Pattern Recognition*, Quebec City,CA, 2002,pp. 216-219.

[8] Jilin, L., Hongqing, M., Peihong, L., “A High Performance License Plate Recognition System Based on the Web Technique,” *IEEE International Conference on Intelligent Transportation Systems*, Oakland, CA, pp. 14-18, 2001.

[9] Lee, S-H., Seok, Y-S., Lee, E-J., “Multinational Integrated Car-License Plate Recognition System Using Geometrical Feature and Hybrid Pattern Vector,” *International*

[10] *Conference on Circuits, Systems, Computers and Communications*, Phuket, Thailand, pp. 1256-1259, 2002.
[11] C. Anagnostopoulos, I. Anagnostopoulos, V. Loumos and E. Kayafas, "A License Plate-Recognition Algorithm for Intelligent Transportation System Applications," *IEEE Transactions on Intelligent Transportation Systems*, vol. 7, No. 3, pp. 377-392, September 2006.
[12] K. -I. Kim, K. Jung and J. -H. Kim, "Color Texture-Based Object detection: An application to License Plate Localization," *In Lecture Notes on Computer Science*, vol.2388, S.-W. Lee and A. Verri, Eds. New york: Springer-Verlag, pp. 293-309, 2002.
[13] Bo Xing, Dequn Liang, Wenju Li, "A novel recognition method of plate number and letter character," *Journal of Liaoning Normal University (natural science edition)*, vol.28, 2005, pp. 56-58 (in Chinses).
[14] Shan Gao, Wanchun Liu, Yuwen Zhu, "The vehicle plate character segmentation and recognition based on SVM," *Microelectronics and Computer*, 2005, vol.22, pp. 34-36 (in Chinese).
[15] Min Wang, Xinhan Huang, Wu Wei, etc, "A vehicle plate character recognition method of pattern matching and neural network," *Journal of Huazhong University of Science and Technology*, 2001, vol.29, pp.48-50 (in Chinese).
[16] Jie Y, Xu L, Wei G, "A recognition of vehicle plate with mathematical morphology and neural networks," *Journal of Wuhan University of Technology (Transportation Science & Engineering)*, 2001, vol.25, pp.371-374 (in Chinese).
[17] Wisam Al Faqheri, Syamsiah Mashohor, "A Real-Time Malaysian Automatic License PlateRecognition (M-ALPR) using Hybrid Fuzzy," *IJCSNS International Journal of Computer Science and Network Security*, 2009, vol.9, pp.333-340.
[18] Konya I., Seibert C., Eickeler S., Glahn S., "Constant-Time Locally Optimal Adaptive Binarization," *Document Analysis and Recognition* (ICDAR '09, 10th International Conference on), 2009, pp. 738-742.
[19] N. Otsu, "A threshold selection method from gray level histograms," *IEEE Transactions on Systems, Man, and Cybernetics*, vol. 9, 1979, pp:62-66
[20] "License plate of motor vechle of the People's Republic of China," Public *security profession standard of the People's Republic of China* GA36 - 2007.
[21] A. Zramdini, and R. Ingold, "Optical font recognition using typographical features," *IEEE Transaction on Pattern Analysis and Machine Intelligence*, vol.20, 1998, pp. 877-882.
[22] FEITOSA, R. Q., VELLASCO, M. M. B., MAFFRA, D. V., ANDRADE, S. S. R. S., OLIVEIRA, D. T., "Facial Expression Classification Using RBF and Back Propagation Neural Networks,"*In:4th World Multiconference onSystemics, Cybernetics and Informatics (SCI'2000) and the 6th International Conference on Information Systems Analysis and Synthesis (ISAS'2000)*, 2000, pp.73 – 77.
[23] Chun Wang, Bo Liu, Xinzhi Zhou, "Research on vehicle plate character recognition based on BP neural network," *China Measurement Technology*, 2005, vol.31, pp. 26-28 (in Chinese).
[24] Li Mengxin, Wu Chengdong, Xia Xinghua, "Pattern recognition method for license plate character based on multilevel RBF network," *Computer Engineering and Applications*, 2008, vol.44, pp.213- 216 (in chinese).

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