An Efficient Binarization Method for Vehicle License Plate Character Recognition

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ABSTRACT

In this paper, to overcome the failure of binarization for the characters suffered from low contrast and non-uniform illumination in license plate character recognition system, we improved the binarization method by combining local thresholding with global thresholding and edge detection. Firstly, apply the local thresholding method to locate the characters in the license plate image and then get the threshold value for the character based on edge detector. This method solves the problem of local low contrast and non-uniform illumination. Finally, back-propagation Neural Network is selected as a powerful tool to perform the recognition process. The results of the experiments illustrate that the proposed binarization method works well and the selected classifier saves the processing time. Besides, the character recognition system performed better recognition accuracy 95.7%, and the recognition speed is controlled within 0.3 seconds.

Key words: License Plate Recognition, Character Recognition, Neural Network, Back-Propagation Algorithm, Support Vector Machine.

1. INTRODUCTION

Automated vehicle license plate recognition (LPR) plays an important role in numerous applications such as parking lots, highway toll-gate, traffic follow measurement and security control of restricted areas. So a robust and reliable LPR system is the main research subject for Korean Plate [1] and other contraries' plates [2,3].

A typical LPR has three main steps: license plate location, character isolation and character recognition. Each step is important for the final recognition result. Edge detection based license plate location algorithm [1-3] is widely applied in practice. 98.45% detection rate is given in Ref. [1], but the final recognition accuracy is 94.37%. Usually the LPR user needs much higher recognition accuracy. So, based on the high detection rate, the following steps need to be enhanced.

Korean license plate characters are printed characters which contains Korean and digits as shown in Figure 1.

Although Optical Character Recognition (OCR) is a mature technique, the character recognition in LPR has its own characteristic. In physical truth, the low recognition rate and low recognition speed are existed. According to the experimental result,

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Korean Classifier / Number Classifier

Fig. 1. The Korean license plate

the failure is mainly caused by smeared license plate and the shadow, non-uniform illumination and low contrast appeared in images. Most of the current literature talked about the recognition of English characters and digits [2-8]. And most of them ignored the weightiness of the binarization operation for the character recognition which is very important for the final recognition result. So in this paper, the binarization will be discussed, and a method which combining global thresholding with local thresholding based edge detection is proposed. The proposed method performed good recognition accuracy. And the recognition speed is satisfied the real time requirement.

The reminder of this paper is organized as follows. Section 2 presents the related works. Section 3 describes the proposed binarization method and the classifier module. Section 4 illustrates the experiments and results. Conclusion is presented in Section 5. Finally, acknowledgements are presented in the last part.

2. RELATED WORKS

In the literature, binarization is performed either globally or locally. For the global methods (global thresholding), a single calculated threshold value is used to classify image pixels into object or background classes [9-12], while for the local methods (adaptive thresholding), local area information guides the threshold value for each pixel [13-16]. Otsu's algorithm[9], a classical global thresholding method, reflects the intensity distribution of animage, but its property of a single threshold results in poor robustness. Although adaptive thresholding methods can deal with some complex images, they often ignore the edge property and lead to a fake shadow. Bernsen's algorithm[14], a classical adaptive thresholding algorithm, computes a separate threshold for each pixel based on the neighborhood of the pixel, so it shows a better adaptation than the global thresholding methods. In order to eval-

uate the performance of binarization methods, Trier and Jain [17] presented a goal-directed evaluation methodology for nineteen methods. Eleven different locally adaptive binarization methods were evaluated, and Niblack's method[13] gave the best performance. Later, SezginandSankur[18] evaluated forty binarization methods based on a combined performance measures, and Kittler's method [11] is the best performing thresholding method in cases of non-destructive testing (NDT) images. Ref. [18] showed that all methods invariably performed poorly for at least one or two images. Thus the combination of thresholding methods can be done at the feature level or at the decision level. Thus edge detection directed binarization techniques have been developed [19-21]. But usually these methods spend more processing time to get the better binarization result which is not satisfied with the real time requirement. So it is difficult for them to be introducedin LPR system.

For LPR system, global thresholding methods are not sufficient since license plate images usually are degraded and have poor quality including shadows, non-uniform illumination, low contrast and smear. So local method is widely used [1,2]. Three local and four local methods are proposed in Ref. [1]. It means the license plate is separated into three or four parts to be binarized separately. The binarization method applied is Niblack algorithm [13]. A variable thresholding technique previously proposed by Nakagawa and Rosenfed [15] is applied in Ref. [2]. This method separated the image into several non-overlapping windows; compute the local threshold value from the local bimodal histogram, but it cannot guarantee the histogram of the window is bimodal. In Ref. [3] simple global method is used which always failed in recognition when the image suffered from non-uniform illumination.

Actually, LPR system's job is to recognize the characters in the license plate as fast as possible, but not to go in for the perfect license plate binary

image. In this paper, we studied the special case in LPR system, applying different threshoding methods to different situations. The proposed threshoding method combined global threshoding with local threshoding and edge detector. The basic idea is: Firstly, we apply the adaptive thresholding algorithm to get the binary plate image and segment the characters by projection method. Record the positions of each character in the plate. Then send the segmented characters to the recognition module, select the characters which cannot be recognized. Secondly, the characters which cannot be classified will be extracted from the gray plate image with the positions recorded in the first step, and they will be regarded as local images. We binarized the local image again by the thresholding method based on edge detection, because the local image doesn't have the enough neighbor domains for analysis, and the adaptive thresholding methods are no longer adapted to this situation due to the small size of the image. Then the rebinarized character will be sent to the recognition module again. The experiments illustrated that rebinarization of the character which cannot be recognized contribute a lot for the final recognition accuracy.

3. PROPOSED BINARIZATION METHOD AND CLASSIFIER MODULE

3.1 Proposed Binarization Method

According to the analysis, we obtain the following method in detail:

Step1: Locate the positions of characters

In this step, the main goal is to locate the characters as fast as possible. Some methods are tested and the results are shown in Figure 2. Ostu's algorithm is failed in binarization of the third image. Niblack's method has a good result in detail but causes a lot of noise. Bersen's method has less noise and can present the character position exactly. In fact, the processing time of Bersen's algorithm is much less then Niblack's algorithm. So
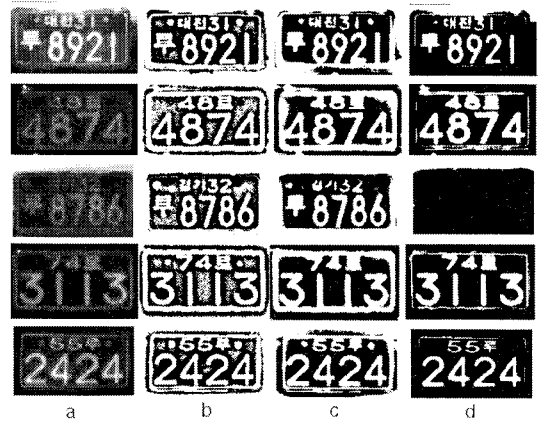

Fig. 2. Comparison among some binarization methods with five license plates: (a) Original image, (b) Niblack method, (c) Bernsen method, (d) Ostu method.

we apply the Bernsen algorithm [14] to get the binary. The window size is one fifth of the height of the image.

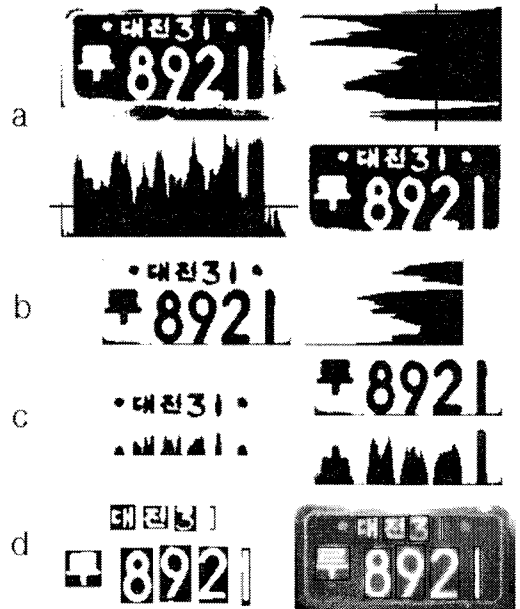The character location process is shown in Figure 3.

Fig. 3. The process of the character extraction in the license plate: (a) Bernsen algorithm, projection and plate without frame, (b) Horizontal projection, (c) Vertical projection, (d) Character extraction.
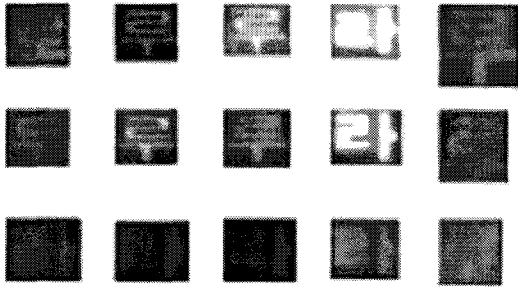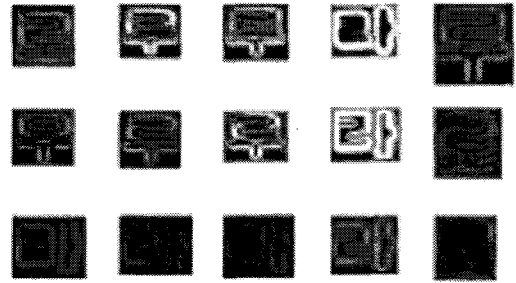
Fig. 4. Mis-recognized by the Elisoft module

Fig. 5. Edge detected by the Prewitt detector

Character extraction is performed by using the horizontal and vertical projection of the binary license plate image, combined with the knowledge of standard characters' position on a license plate.

As the single character was obtained, we find the Korean character "루" shown in the Figure 3 (d) would be misrecognized as "무" or others. This kind of problem causes the recognition failure. Figure 4 shows some other characters which are misrecognized under the Elisoft module.

So the next step rebinarization is introduced in the next part.

Step2: Rebinarization of the character

The located Korean character is regarded as a local image. Because the size of the extracted character is very small, the histogram is not credible due to the low contrast of the image. To overcome the defect of the Ostu algorithm, in this step, we introduced edge detector which can give the position information. The rebinarization step is shown as follows:

  A. Edge detection

  B. Analysis of histogram of the background and foreground

  C. Binarization

A. Edge detection

We used the Prewitt detector because of its high efficiency. It is summarized as follows. I[i,j] denotes the pixel value, the horizontal derivative H[i,j] and vertical derivative V[i,j] were calculated by formula (1) and (2). The edge images are shown in Figure 5.

$$H[i,j] = \frac{\sum_{k=-1}^{1} I[i+k, j-1] - \sum_{k=-1}^{1} I[i+k, j+1]}{6} \quad (1)$$

$$V[i,j] = \frac{\sum_{k=-1}^{1} I[i-1, j+k] - \sum_{k=-1}^{1} I[i+1, j+k]}{6} \quad (2)$$

And the magnitude of the gradient is computed as below:

$$M[i,j] = \sqrt{H[i,j]^2 + V[i,j]^2} \quad (3)$$

B. Analysis of histogram of the background and foreground

In this step, only the pixels around the edges were be calculated, because the background and foreground pixels are located around edges. A proper magnitude threshold is essential to determine the edges in the image. It is formula (4), where M_{max} is the maximum value of M in the image. It is a got by the experience.

$$T = 40\% \times M_{max} \quad (4)$$

The pixel whose magnitude is larger than T will be regarded as edge, and then 8-neighbor domain pixels of the edge were regarded as background and foreground pixels. As shown in Figure 6. The white pixels are the background and foreground pixels.

We take the character '루' in the top right of the image in Figure 4 for example to analyze the histogram. The original histogram and the histogram obtained after locating the background and foreground pixels are shown in Figure 7.
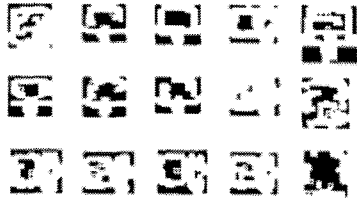
Fig. 6. Background and foreground pixels (white pixels).

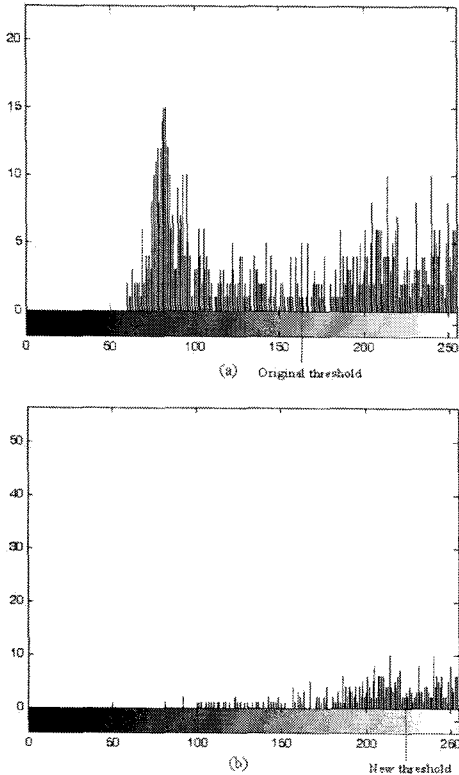(a) Original threshold

(b)   New threshold

Fig. 7. (a) The histogram of the original image "루", (b) The histogram based on edge detector.

As the histogram (b) shown, the pixels whose value is from 70 to 100 are ignored by our background and foreground pixel location process. Actually it is the main factor that causes the wrong thresholding. After the background and foreground pixels location process, this kind of problem can be solved.

C. Binarization

After getting the new histogram of the image,

the Ostu algorithm which is regarded as the best binarization method based on histogram is applied. The algorithm is summarized by the following notation.

For the gray threshold k between 0 and 255, the pixels were separated into two groups. The pixel number of goup 1 is presented as $\omega_1(k)$, the average gray value $M_1(k)$, variance $\delta_1(k)$; and the second group pixels: number is $\omega_2(k)$, average gray level is $M_2(k)$, variance is $\delta_2(k)$. And then compute the formula (5):

$$\delta = \omega_1 \omega_2 \left(M_1 - M_2 \right)^2 \tag{5}$$

When finding the maximum of δ, the current value of the k is the threshold we need as shown in Figure7(b). With the new threshold, the binary image of the character'루' was obtained in Figure 8.
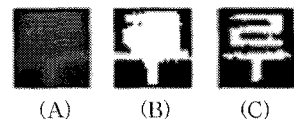
The other binarization result is illustrated in Figure 9.

(A)   (B)   (C)

Fig. 8. Rebinarization of local character. (A) Extracted Korean character. (B) Ostu algorithm. (C) Our method.

(A)

(B)
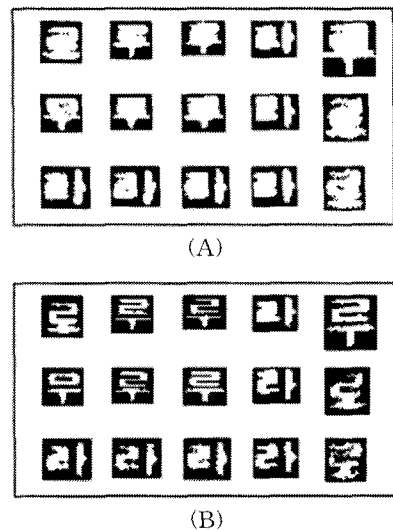
Fig. 9. (A) Ostu algorithm (B) Our method

3.2 Classifier Module

Active researches of several decades in the field of vehicle license character have led to some efficient feature-based character recognition approaches: one is OCR based on template matching [1,4,5], and the other is OCR based on neural network (NN) classifier[2,3,6,7]. There are some researchers combined the two methods together[22]. New learning methods especially support vector machines (SVMs) [23,24], are now actively studied and applied in pattern recognition.

The classifier for LPR system needs meet two requirements. One is the classification accuracy, the other is classification speed. The SVM classifier have been demonstrated better classification accuracies to neural network, but SVM learning by quadratic programming (QP) often results in a large number of SVs, which should be stored and computed in classification. Neural classifiers have much less parameters, and the number of parameters is easy to control. In a word, neural classifiers consume less storage and computation than SVMs. So in this paper, we chose neural classifier. It was reported that more than 90% of the neural network applications in the industry have used back-propagation (BP) neural network. The algorithm can be found in Ref. [25].

In our situation, the license plate character is a limited set, so 3-layers BPNN was utilized in our application. The input size of the Korean classifier is 256(16*16), the input size of the number is 128(8*16). Output size of the Korean classifier is 6 and the output size of the number classifier is 4, they were coded by '8421' code, take the number classifier, for example, '0000' is the number '0', '0001' is the number '2'⋯⋯ '1001' is the number '9'. But because the sigmoid function can not output 0 and 1, when training the net '0' is replaced by 0.1, and '1' is replaced by 0.9.

The activation function is sigmoid function, and the initialized value of the weights are uniformly distributed between -1 ~ 1, the momentum is 0.9.

The learning rate is 0.8. The minimum of the squared error is 0.0001.

For LPR system, the learning of the neural network is not the topic we care about. We care about the recognition speed and the recognition accuracy. The recognition speed and accuracy are related to the structure of the neural network. Because the input and output size are decided by the physical truth. So the recognition speed is related to the number of nodes in hidden layer. Take Korean classifier for example, 300 character images are used as the patterns for neural network training. Some of the dataset are shown in Figure 10. They are resized into 16*16. 1000 Korean characters are tested by the neural network. The relationship between the hidden layer size and the recognition accuracy is shown in Figure 11.

According to the Figure 11, the recognition accuracy is increasing by the number of the nodes in the hidden layer. But care about the recognition
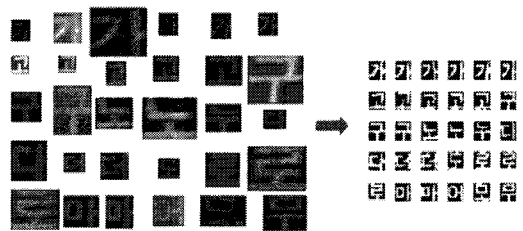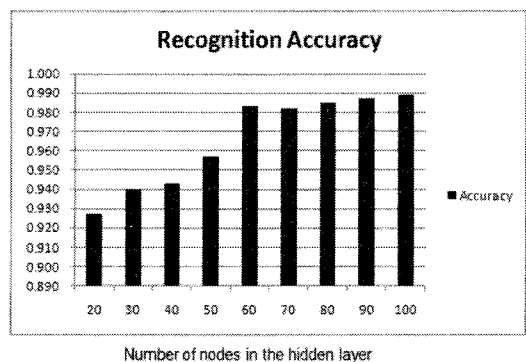

Fig. 10. Example of the trainning dataset

Fig. 11. Recognition accuracy for different number of nodes in the hidden layer, for goal = 0.0001, learning rate = 0.8, momentum = 0.9.

speed, 60 is a reasonable number for our system. By the same method, the number of the nodes in the hidden layer for number classifier is set to 40.

4. EXPERIMENTS AND RESULTS

To illustrate the effectiveness of the proposed system, experiments have been conducted on lots of characters as shown in Figure 12.

We used VC++ to do the system. Computer configuration is Intel(R) Pentium(R) D CPU 3.40GHz. Five hundreds 1024*768 images are tested. The comparison between the recognition rates of several binarization methods is shown in Table 1. The comparison between the BPNN and SVMs [24] is shown in Table 2.

The experimental results show that the whole recognition accuracy is more than 95.7% which is increased 1.4% compared with the system in Ref. [1] and the recognition time is less than 0.3s. The recognition time means the processing time from gray character image to the recognition result. We found the SVMs classifier is not satisfied with the LPR system due to the time consuming of the recognition process, though it performs the best recognition accuracy.
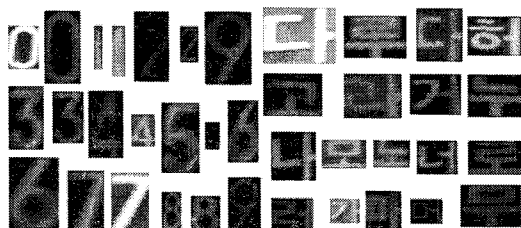

Fig. 12. The test datas for the proposed method

Table 1. Comparison between the recognition rates of several binarization methods

	Korean	Number	Whole
Niblack	83.00%	96.67%	77.00%
Bersen	78.67%	96.33%	73.00%
Ostu	76.33%	93.33%	70.33%
Our method	96.37%	98.45%	95.73%

Table 2. Comparison between the BPNN and SVMs classifier

	Accuracy / Time	Korean	Number
BPNN	Accuracy	96.4%	98.5%
	Time	0.231 s	0.047 s
SVMs	Accuracy	97.2%	99.7%
	Time	6.462 s	1.031 s

5. CONCLUSIONS

In this paper, we have proposed an efficient character recognition model for the LPR System. In the license plate binarization step, we pay more attention to the binarization speed than the result, because the aim of LPR is to recognize the character but not get the most clear binary image. So firstly, we apply fast adaptive thresholding method to locate the characters, and then analyze the histogram of the character which is obtained based on edge detector. The proposed method can solve the problem of reorganization failure caused by the low contrast and non-uniform illumination. And more, it saves the processing time. The BPNN classifier is selected as a powerful tool to solve the classify problem. And the recognition speed is very fast. The experimental results demonstrated that it has superior recognition speed to SVMs classifier which is an important target in LPR system. So BPNN classifier is more feasible in practice. Finally, the proposed recognition module performs the 95.7% recognition accuracy and the recognition speed is controlled within 0.3 seconds.

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REFERENCES

[1] Mei Yu, Yong Deak Kim, "An approach to Korean license plate recognition based on

vertical edge matching," IEEE System, Man and Cybernetics, Vol. 4, No. 8-11, pp. 2975-2980, 2000.

[2] Shyang-Lih Chang; Li-Shien Chen; Yun-Chung Chung; Sei-Wan Chen; "Automatic License Plate Recognition," IEEE Transaction on Intelligent Transportation System, Vol.5, Issue 1, pp. 42-53, Mar. 2004.

[3] Sherin M, Youssef, Shaza B. AbdelRahman. "A smart access control using an efficient license plate location an recognition," Expert Systems with Applications, Vol.34, Issue 1, pp. 256-265, Jan. 2008.

[4] Shen-Zheng Wang; Hsi-Jian Lee; "Detection and Recognition of License Plate Characters with Different Appearances," IEEE Intelligent Transportation System. Vol.2, No.12-15, pp. 979-984, Oct. 2003.

[5] Rahman, C.A.; Badawy, W.; Radmanesh, A.; "A real time vehicle's license plate recognition system," Proceedings. IEEE Conference on Advanced Video and Signal Based Surveillance, 21-22, pp. 163-166 July 2003.

[6] Nukano, T.; Fukumi, M.; Khalid, M. "Vehicle License Plate Character Recognition by Neural Networks," Intelligent Signal Processing and Communication Systems, 2004. ISPACS 2004. Proceedings of 2004 International Symposium on, 18-19, pp. 771-775, Nov. 2004.

[7] Abdullah, Siti Norul Huda Sheikh; Khalid, Marzuki; Yusof, Rubiyah; Omar, Khairuddin; "Comparison of Feature Extractors in License Plate Recognition," 27-30, pp. 502-506 Mar. 2007.

[8] Pu Han; Wei Han; Dong-Feng Wang; Yong-Jie Zhai. "Car license plate feature extraction and recognition based on multi-stage classifier," IEEE International Conference on Machine Learning and Cybernetics Vol.1, 2-5, pp. 128-132, 2003.

[9] Otsu N, "A threshold selection method from gray-level histograms," IEEE Transactions on Systems, Man and Cybernetics, Vol.9, No.1, pp. 62-66, 1979.

[10] J.N. Kapur, P.K. Sahoo, A.K. Wong, "A new method for gray-level picture thresholding using the entropy of the histogram," Comput. Vision Graphics Image Process. Vol.29, No.3 pp. 273-285, 1985.

[11] J. Kittler, J. Illingworth, J. Foglein, "Minimum error thresholding," Pattern Recognition Vol. 19, No.1, pp. 41-47, 1986.

[12] Feng Yang, Zheng Ma, Mei Xie, "A Novel Binarization Approach for License Plate," IEEE Conference on Industrial Electronics and Applications, pp. 1-4, 2006.

[13] W.Niblack, "An introduction to digital image processing," Prentice-Hall, Englewood Cliffs, N.J., pp. 115-116, 1986.

[14] J.Bernsen. "Dynamic thresholding of gray-level images," in: Proceedings of the Eighth International Conference on Pattern Recognition, Paris, IEEE Computer Society Press, France, pp. 1251-1255, 1986.

[15] Y. Nakagawa and A. Rosenfeld, "Some experiments on variable thresholding," Pattern Recognition, Vol.11, No.3, pp. 191-204, 1979.

[16] I.-K. Kim, D.-W. Jung, R.-H. Park, "Document image binarization based on topographic analysis using a water flow model," Pattern Recognition, Vol.35, Issue 1, pp. 265-277, Jan. 2002.

[17] Trier.O.D, Taxt.T, "Evaluation of binarization methods for document images," IEEE Pattern Analysis and Machine Intelligence, Vol.17, Issue. 3, pp. 312-315, 1995.

[18] M. Sezgin, B. Sankur, "Survey over image thresholding techniques and quantitative performance evaluation," J. Electronic Imaging Vol.13, Vol.1, pp. 146-165, 2004.

[19] Moon-Soo Chang, Sun-Mee Kang, Woo-Sik Rho. "Improved binarization algorithm for document image by histogram and edge de-

tection," Proceedings of the Third International Conference on Document Analysis and Recognition, Vol.2, No.14-16, pp. 636-639, 1995.

[20] Huang, Songtao; Ahmadi, Majid; Sid-Ahmed, M.A. "An edge based Thresholding Method," IEEE International Conference on Vol.2, No.8-11, pp. 1603-1608, 2006.

[21] Qiang Chen, Quan-sen Sun, Pheng Ann Heng, De-shen Xia. "A double-threshold image binarization method based on edge detector," Pattern Recognition Vol.41, Issue 4, pp. 1254-1267, 2008.

[22] Lu Xiaobo; Ling Xiaojing; Huang Wei; "VEHICLE LICENSE PLATE CHARACTER RECOGNITION," Neural Networks and Signal Processing, Vol.2, No.14-17, pp. 1066-1069, Dec. 2003

[23] C.J.C. Burges. "A tutorial on support vector machines for pattern recognition," Knowledge Discovery and Data Mining, Vol.2, No.2, pp. 1-43, 1998.

[24] Bouchareb, Faouzi; Hamdi, Rachid; Bedda, Mouldi, "Handwritten Arabic character recognition based on SVM Classifier," Vol.7, No.11, pp. 1-4, Apr. 2008.

[25] S.Rajasekaran, G.A. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic, and Genetic Algorithms Synthesis and Applicitions," Prentice-Hall of India Private Limited Publisher, 2005.

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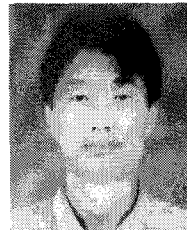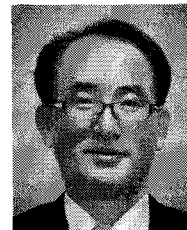
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