A Recognition System of China-style License Plates Based on Mathematical Morphology and Neural Network

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***Abstract*—**Vehicle license plate recognition system is the hardcore of the intelligent traffic system. Through the research of four key links of the license plate location, image pre-processing, character segmentation and character recognition, the paper has designed an intact license plate recognition system and has implemented the simulation in the environment of MATLAB. The license plate location, which is based on colour character and vein character, has realized the thick location of the blue bottom and white word license plate. The image pre-processing, which is included gray processing, binary processing and the license plate slant correction to the horizontal line, is adopted by the related operation of mathematical morphology and Radon transformation**.** Character segmentation is based on the improved horizontal projection. Aiming at the characteristic of China-style license plates, the character recognition is proposed to use four kinds of different classification devices by using the improved BP neural network. This system is effective for solving the problems which are Chinese character unconnected, cement of the character, illumination variance and interference of the noise and space mark.

***Keywords*—**Artificial neural network, Character segmentation, Image processing, License plate recognition, Mathematical morphology, Radon transformation.

I. Introduction

License plate recognition (LRP) system plays an important role in traffic surveillance systems, such as traffic law enforcement, real-time monitoring and parking systems, road monitoring and security systems as in [1] [2]. Recognizing the license plate of a vehicle from a natural image is a complicated process that involves the detection of the license plate and recognition of character on the plate. Many techniques have already been suggested as in [3] [4]. The vehicle image was captured by the Charge Coupled Device camera fixed on both sides and the top of the channel. Because of the impact of the distance between the lens and the plates, cars driving speed, license plate position and so on, the license plate always had certain gradient, which had the bad effect on its character segmentation and recognition. Therefore, license plate must be corrected before character segmentation and character recognition. In this paper, an experimental system for the LRP of China-style license plates is presented. The proposed system consists of four phases, license plate location, image pre-processing, character segmentation and character recognition, whose functions are briefly described as following.

License plate location: This phase extracts license plate candidate regions from a complex scene. We adopted the license plate location method, which is based on colour character and vein character. At first, colour picture is changed from RGB space into HSI space. The thick location of the license plate has realized by using the character of blue colour degree and value of saturation degree. Finally according to the character of license plate image's high-frequency of changing black-and-whitely, we realized the accurate location of the license plate.

Image pre-processing: The image pre-processing is included gray processing, binary processing and the license plate slant correction to the horizontal line. Pictures of license plates are generally colourful. If the colourful pictures are processed directly, it will lower the processing speed of system. Therefore, the colourful information of license plates should be processed to obtain grayscale pictures. In fact, because the side frame and the Upper and Lower rivets of license plate will interfere with the recognition of license plate, we will remove the side frame and the Upper and Lower rivets.

Character segmentation: Segmentation was carried out using the improved horizontal projection, then the segmented characters are scaled. This method is effective on solving the

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problems which are Chinese character unconnected, cement of the character, interference of the noise, space mark and illumination variance.

Character recognition: The improved BP neural network is proposed to use recognition of license plate characters. The training vector of neural network consists of 256 elements. It can be created by vectors of image rows of the license plate characters in binary format.

The rest of this paper is organized as following: section 2 introduces License plate thick Location. The image pre-processing is presented in Section 3. Section 4 describes character segmentation. Character recognition is showed in Section 5. The experimental results and conclusion remarks on the work are drawn in Section 6.

II. LICENSE PLATE LOCATION N

A. Revise the color model of plate regions

In order to extract the license plate from the image, the main characteristic of the license plate should be seized accurately. A pixel of 24-bit BMP images takes three bytes in memory, which contents red, green and blue color information. The image we get from common computers is described using RGB model. In this model, we use the value of red, green and blue to denote each color. This model is affected by illumination. So we translate RGB model into HSI model to get plate color information under the condition of various illumination .The color pictures of HSI model are described using Hue, Saturation and Intensity. The hue denotes the attribute of every pure color. The saturation is measurement of the degree which a pure color is diluted by white light. The intensity denotes the value of image gray scale as in [5]. RGB model translated to HSI model as follow:

$$I = \frac{1}{3}(R + G + B) \tag{2.1}$$

$$S = 1 - \frac{3}{R + G + B}[\min(R, G, B)] \tag{2.2}$$

$$\theta = \arccos\left\{ \frac{\frac{1}{2}[(R-G) + (R-B)]}{[(R-G)^2 + (R-G)(G-B)]^{1/2}} \right\} \tag{2.3}$$

Where $\theta \in [0,2\pi)$, $S \in [0,1]$, I [0,255]. If $B \le G$, $H = \theta$; if $B > G$, $H = 360° - \theta$. Blue degree is about 240°. And S value of saturation degree is bigger. According to the characteristic we can locate the license plate in the license plate of blue plate and white characters. We give an example with blue plate and white characteristic in blue car First we translate RGB image into HSI image. Then we filter blue range of the car by taking into account the values of H and S. The result is given in Fig. 2.1

Fig. 2.1 : the filtered image

B. Accurate location of license plat

The texture of license plate is mainly contour of plate characters. Obviously an edge is composed by a set of conjoint pixels, which lie on the region of gray scales break. So we usually use the derivatives to detect the edge pixels in the image. Actually there are a lot of the methods of edge detection. Here we use Canny filter to process. The edge image of Fig.2.1 is shown in Fig 2.2 after Canny operator filtering.

Fig. 2.2 Edge image of Canny operator filtering

The image of Canny operator filtering is the binaries image. According to Fig. 2.2 the plate regions have more edge information than other regions on the image. It is owing to the great contrast of characters and the plate image. And the plate region characters arrange in a certain interval level. The characters have a certain width. The colors of characters and plate are comparatively single. So we can use these characteristics to locating the plate regions by line scanning algorithm. The line scanning algorithm as following:

1. Scanning every horizontal lines of the image;
2. Getting the value of changing times between white and black pixel in every line;
3. Up and down Scanning from the line that the change value of pixel is more than other lines.
4. If the change times are less than a threshold between white pixel and black pixel, we will stop scanning. The upper and lower horizontal lines of stopping scanning are upper and lower borders of the plate license.

The results of horizontal line scan are shown in Fig. 2.3:

Fig 2.3 the binary image of up and down location

Similarly, we scan every vertical line of the image showed in Fig 2.3. By using same method, we can get the left and right borders of the plate license. The results of location are shown in Fig. 2.4.

Fig. 2.4 the plate image of accurate location

It can be seen from Fig. 2.4 that the effect of plate location is satisfactory, although color of car and plate is same.

III. Image Pre-processing

The pictures of license plates are generally colourful. If the colourful pictures are processed directly, it will lower the processing speed of system. Therefore, the colourful information of license plates should be processed to obtain greyscale pictures. The image pre-processing also includes plate slant correction to the horizontal line, which is adopted by the related operation of mathematical morphology and Radon transformation.

A. Gray processing

The colourful pictures contained thousands of bits information. When the colourful pictures are processed directly, the execution speed of processing system will decrease. Therefore, colourful information of the located plate pictures should be processed to obtain greyscale pictures.

A pixel of 24-bit BMP images takes three bytes in memory, which content red, green and blue color information. We denote red, green and blue with R, G and B. The grey value is showed by g. We have following three formulas that turn the images into gray image as in [6]:

$$g = \max(R, G, B) \quad (3.1)$$

$$g = \frac{R+G+B}{3} \quad (3.2)$$

$$g = \frac{0.3R + 0.59G + 0.11B}{3} \quad (3.3)$$

Because eyes are more sensitive to green, the parameter of green is the maximum. We will use equation (3.3) in this paper.

B. Edge detection based on mathematical morphology

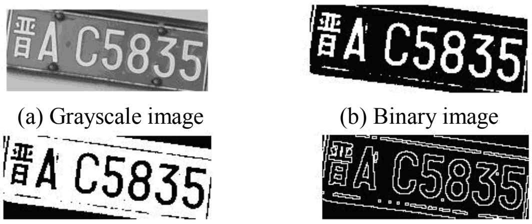
Morphology closing operation can be used to restrain noises, extract feature, detection edge and so on. The primary transformations of mathematical morphology are dilation and erosion. Opening and closing operation are two other important morphological operations composed of dilation and erosion. Morphology operator mainly uses morphology gradient. Though it is sensitive to the noises, it can't enhance or magnify noises as in [7]. The most essential morphology gradient is defined as following:

$$\mathrm{Grad}_1 = (\mathrm{A} \oplus \mathrm{B}) - (A \Theta \mathrm{B}) \quad (3.4)$$

The morphology gradient used by aculeate edge is defined as following:

$$Grad_2 = (\mathrm{A} \oplus \mathrm{B}) - A \quad (3.5)$$

Where A denotes image, B denotes a structure element. According to the above description, the morphology erosion edge detection was presented using the second morphology operator in the paper. Furthermore, we used Otsu method to change grayscale image into binary image. Then edge detection was performed by using the morphology erosion algorithm. We take advantage of the decomposition of the structuring element object erode the binary image. The edge detection process is shown in Fig. 3.1.



(a) Grayscale image (b) Binary image

(c) Negated image (d) Edge image

Fig.3.1 The process of the mathematical morphology edge detection

C. Horizontal slant vehicle license plates correction

The performance of character segmentation is sensitive to skew. Therefore skew detection and correction are critical. This problem can be solved with the Radon transformation.

Radon transformation can be defined in any dimension variable space region. We consider the form in two-dimensional Euclidean space. The transformation is conducted as below as in [8]:

$$R(\theta, \rho) = \iint_D f(x,y)\, \delta(\rho - x\cos\theta - y\sin\theta)dxdy \quad (3.6)$$

Where, D denotes the whole image plane. Eigen function is denoted by Dirac function. The pixels gray value of a point (x, y) is noted as $f(x, y)$ in the image. The distance from origin to straight line is noted as ρ in $x-y$ domain. θ is defined as the angle between the vertical line and x axis, which is from origin to straight line. The geometry of the Radon transform is showed in Fig.3.2 as in [9]. We can see that the straight line is well-determined when ρ and θ are fixed values. In turn, each straight line in $x-y$ domain represents a point in $\rho-\theta$ domain. So Radon transformation mapped the straight line in $x-y$ domain to a point in $\rho-\theta$ domain.

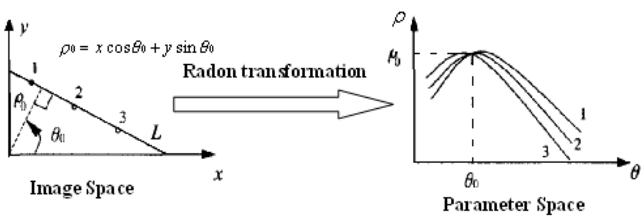


Fig.3.2 Sketch map of Radon transformation

The Radon transform is closely related to a common computer vision operation known as the Hough transform. We can use the radon function to detect straight lines of slant vehicle license plates. The steps are given as following.

Step1. Obtain a binary edge image using the mathematical morphology erosion algorithm.

Step2. Compute the Radon transform of the edge image.

Step3. Find the locations of strong peaks in the Radon transform matrix. The locations of these peaks correspond to the locations of straight lines in the origin. The longer the straight line is, the brighter the corresponding point is. These peak points are arranged in descending order in Radon space in view of the veracity. Choose the front several peaks, calculate the sum of each row and put them in matrix R .then run the following orders:

$$\begin{aligned}&for \quad i = 2 : length(R)\\&\qquad E(i) = a * R(i) + (1-a) * E(i-1);\\&end\end{aligned}$$

Get the maximum of $E(i)$, $\alpha = |90° - i|$ is horizontal rotation angle.

Step4. Lossless rotation correction is performed to the slant plate in the horizontal direction.

The result of horizontal slant correction for Fig.3.1 is shown in Fig.3.3.

Fig. 3.3 Result of Horizontal slant image correction

IV. Character Segmentation

There are many factors that cause the character segmentation task difficultly, such as image noise, plate frame, rivets, space mark, and illumination variance. Our algorithm, the improved horizontal projection, overcomes the difficulties mentioned above. This method is effective on solving the problems, which are Chinese character unconnected, cement of the character, illumination variance, interference of the noise and space mark. In order to segment the individual characters, we project license plate images vertically using grey level values. Then we introduce the thresholds for segmentation.

The improved horizontal projection as following:

1. Scan the pre-processing image from left to right, and record the white pixel(the pixel of character is white);
2. On Chinese license plate, first letter is Chinese character. According to the feature of Chinese characters, we set two thresholds to segment first Chinese character. We scan the pre-processing image from left to right. When white pixel value of the first vertical line is more than first threshold, the vertical line is starting position of Chinese character, Then continuing scan, when white pixel value of the vertical line is less then first threshold, we compare the width between the two vertical lines with second threshold. If the width is less then second threshold, continuing scan until finding the vertical line when the width between two vertical lines is more then second threshold. Then the vertical line is end position of Chinese character. This method is effective on solving the unconnected problems of some Chinese characters.
3. Next seventh characters of license plate are English letters and numbers. There is not unconnected problem. So we just use first threshold to segment. When first Chinese character is segment, we continue scan. When white pixel value of the vertical line is more than first threshold, the vertical line is starting position of next letter. When white pixel value of next vertical line is less than first threshold, the vertical line is end position of the letter. And so forth, until all letters and number are segmented.

The examples of segmentation are shown in Fig.4.1 and Fig.4.2:

Fig.4.1 original image of located plate

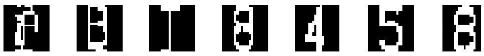


Fig. 4.2 segmented image

Characters segmented from different car plates have different sizes. We use a linear normalization algorithm to adjusting the input image into a uniform size (in our implementation, 16×16 pixels).

V. Character Recognition

The improved BP neural network is proposed to use recognition of' license plate characters. The training vector of neural network consists of 256 elements. It can be created by vectors of image rows of the license plate characters in binary format. So far there are a number of techniques, which is used the recognition of license plates, such as vector quantization, template matching and neural network etc as in [10]-[12]. It is proposed to use artificial neural networks for recognizing of license plate characters in this paper. In general, the BP algorithm includes the forward course and the backward course.

A. An introduction of BP networks

A BP network with a hidden layer can approximate with arbitrary precision an arbitrary nonlinear function defined on a compact set of R^n as in [13]-[15]. BP algorithm is a training algorithm with teachers, whose training procedures are divided into two parts: a forward propagation of information and a backward propagation of error. The network's training procedures is described below.

Let the node numbers of in put and hidden layer be N and M respectively. In this paper, the node number of the output layer is ascertained as 1. Let the input example vectors be $\xi^{\mu}=(\xi_1^{\mu},\xi_2^{\mu},\cdots,\xi_N^{\mu})\,(1\le\mu\le P)$. Denote by $w_{ij}\,(1\le i\le N, 1\le j\le \le M)$ the weight connecting the ith input node and the jth hidden node. Denote by $W_j\,(1\le j\le M)$ the connection weight between the jth hidden node and the output node. $g(x)$ and $f(x)$ are the activation functions of the hidden layer and the output layer respectively. When training example ξ^{μ} are input to the network, the input and output values of the *j*th hidden node are denoted as x_j^{μ} and $y_j^{\mu}\,(1\le j\le M, 1\le\mu\le P)$ respectively, while the input values and output values of the output unit are denoted by H^{μ} and $O^{\mu}\,(1\le\mu\le P)$ respectively. In symbol we have

$$x_j^{\mu}=\sum_{i=1}^{N} w_{ij}\xi_i^{\mu}\cdot \tag{5.1}$$

$$y_j^{\mu}=g(x_j^{\mu}) \tag{5.2}$$

$$y_j^{\mu}=g(x_j^{\mu}) \tag{5.3}$$

$$H^{\mu}=\sum_{j=1}^{M} W_j y_j^{\mu} \tag{5.4}$$

$$O^{\mu}=f(H^{\mu}) \tag{5.5}$$

Let the desired output corresponding to the input example ξ^{μ} be ζ^{μ} . (According to the type of output layer's activation functions, ζ^{μ} are chosen as (0,1) in this paper). Then the square error function for this step of training is

$$E_{\mu}=\frac{1}{2}(\zeta^{\mu}-O^{\mu})^2\cdot \tag{5.6}$$

The overall square error function after all example are used is

$$E=\frac{1}{2}\sum_{\mu=1}^{P}(\zeta^{\mu}-O^{\mu})^2\cdot \tag{5.7}$$

Let W denote the vector containing all the weights. The purpose of BP algorithm is to choose W so as to minimize the error function by, say, the gradient descent method. So the general expression of the iteration formula is

$$W(t+1)=W(t)+\Delta W(t), \tag{5.8a}$$

where

$$\Delta W=\eta\left(-\frac{\partial E}{\partial W}\right)\Bigg|_{W=W(t)} \tag{5.8b}$$

is the weight increment at time *t*, and the positive constant η is the training ratio, 0< η <1.

In practical application, a momentum term is often added to Formula (1.7) to accelerate the convergence speed, resulting in

$$\Delta W=\eta\left(-\frac{\partial E}{\partial W}\right)\Bigg|_{w=w(t)}+\alpha[w(t)-w(t-1)], \tag{5.9}$$

where the positive constant α is a momentum factor. 0< α <1.

A popular variation of the standard gradient method is a so called *online gradient method* (OGM for short). This means that the weight values are modified as soon as a training example is input to the network. Now we have

$$\Delta W_j=\eta\left(-\frac{\partial E}{\partial W_j}\right)=\eta(\zeta^{\mu}-O^{\mu})f'(H^{\mu})y_j^{\mu} \tag{5.10}$$

By the chain rule and (5.1)-(5.5), we have

$$\Delta w_{ij}=\eta\left(-\frac{\partial E}{\partial w_{ij}}\right)=\eta(\zeta^{\mu}-O^{\mu})f'(H^{\mu})W_j g'(x_j^{\mu})\xi_j^{\mu}, \tag{5.11}$$

The training examples $\{\xi^{\mu}\}$ are usually supplied to the network in stochastic order.

It is more likely for OGM to jump off from a local minimum of the error function, compared with the standard gradient method, and it requires less memory space. Therefore, OGM is widely used in neural network training.

After weight values W_j and W_j are determined through network training, we supply to the network with an input vector ξ with respect to a certain day's SARS situation, resulting in an output value O according to (5.1)-(5.4), which predicts the SARS propagation in nest day.

We use a three-layer BP network with OGM to study the SARS epidemic. The activation function of the output layer is a S (sigmold) function $f(x)=\dfrac{1}{1+e^{-x}}$, while the activation function of the hidden layer is $g(x)=\dfrac{1}{1+e^{-\beta x}}$ $(0<\beta\le 1)$. Usually small initial weight values are chosen, otherwise the activation function will reach saturation in the beginning of training and the network will fall into local minimum around the initial. Based on numerical experiment, initial weight values are chosen randomly in the interval (0, 0.1).

B. Architecture of BP networks

The BP neural network contains inputs, neurons of the hidden layer and neurons of output layer. The outputs of every intermediate layer are the inputs of the next layer. The images of characters (16x16 pixels) form the training set of neural network. The BP neural network is used for character recognition. The training vector of neural network consists of 256 elements. It can be created by vectors of image rows of the license plate characters in binary format.

In the part of character recognition, aiming at four kinds of different recognition problems of Chinese character, the letter, letter or figure, figure, the paper has designed four kinds of different classification devices by using the improved BP neural network. Utilizing 13 features extraction, the paper regards its result as the input of the network. Finally, the license plate number is composed of different recognition results.

VI. Experimental Result and Conclusion

Through the research of four key links of the license plate location, image pre-processing, character segmentation and character recognition of the license plate recognition system, this paper has designed an intact license plate recognition system and has implemented the simulation in the environment of MATLAB. The experiment consists of two parts. One part of the experiment is carried with the images of license plate, which are not skew plate. Another is with the images of skew license plate.

A. No skew license plate experiment

In the part, 260 images of license plate are employed for experiment. All of them were taken by CCD camera from various scenes and under different conditions of the real world, including different lightening conditions. These images are not skew license plate. The results show that the average speed is 3ms time-consuming for a license plate. The success detection rate of characters is up to 76%.

The system is implemented with MATLAB. The implementation process are shown in Fig.6.1, Fig. 6.2 , Fig. 6.3 and Fig. 6.4.t

Fig.6.1 Location result of license plate

Fig. 6.2 Pre-processing result of license plate

Fig. 6.3 Character segmentation result

Fig. 6.4 Character recognition result

B. Skew license plate experiment

In this part, 52 images of license plate are employed for experiment. All of them were taken by CCD camera from various scenes, different conditions, diverse angles and different lightening conditions of the real world. A majority of license plate images have different horizontal skew angle. The results show that the average speed is about 3ms time-consuming for a license plate. The success detection rate of characters is up to 73.1%. There are three license plate images that are not location and segmentation successfully.

The experiment is implemented with MATLAB. The implementation process is shown in Fig.6.5, Fig. 6.6, Fig. 6.7, Fig. 6.8 and Fig. 6.9.

Fig. 6.5 System initialization interface diagram

Fig. 6.6 Location and correct of license plate

Fig. 6.7 Pre-processing result of license plate

Fig. 6.8 System Character segmentation results

Fig. 6.9 System Character recognition results

C. Conclusion

Because of character recognitions are generally very sensitive to skew plate. Therefore, skew detection affect recognition rate of license plate. If the images of license plate do not have skew, the recognition rate will greatly be improved. In addition, the recognition rate of English letters and numeral are high then that of Chinese letter. The result of the experiment, we can see the proposed approach is robust. Yet there are still some images failed to detect in the experiment (especially skew images). We will improve the performance of the algorithm through skew correction of license plate further and Chinese letter recognition of license plate.

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