License Plate Location Based on Simplified Pulse Coupled Neural Network and Comprehensive Feature

XIE Guangjun
College of Information Science and Engineering
Hunan University
Changsha Hunan, China

REN Xiaoxi
College of Information Science and Engineering
Hunan University
Changsha Hunan, China

***Abstract*—License plate location is the key of the license plate recognition system. In order to accurately to locate the license plate region in the complex environment, this paper puts forward a license plate locating method based on simplified pulse coupled neural network and comprehensive feature. Firstly, pre-processing and morphological filtering on the vehicle image, and extract the license plate candidate area based on the structure features of the license. Then, doing color analysis in the candidate area of HSV color space to achieve coarse location of license plate. After that, using simplified Pulse Coupled Neural Network (PCNN) for image binarization and using the radon transform of license plate to tilt correction. Finally, get the accurate localization of the correction results of license plate by line scan and vertical projection. The experimental results show that the algorithm has high accuracy, good robustness and can meet the real-time requirement.**

Keywords—license plate location; Pulse Coupled Neural Network; morphology; Color analysis; line scan; Vertical projection

I. INTRODUCTION

As the key technology of the intelligent transportation system, license plate recognition technology includes license plate location, character segmentation, character recognition three parts. License plate location is the most crucial step, the accuracy of the license plate location has a direct effect on the character segmentation and recognition performance.

At present, the domestic and foreign scholars have proposed many kinds of license plate location algorithm, which mainly divided into two categories: based on color image and based on gray image. And the former can be subdivided into gray image based on texture analysis [1], based on edge detection [2], based on morphology [3], based on wavelet analysis [4] and based on neural networks [5]. The latter generally include color image edge detection [6] and in RGB and HSV color space for color image segmentation [7]. Method described above can locate in certain circumstances, but most of them have limitations. Method based on texture analysis is very sensitive to disturbance, often leads to inaccurate position.Method based on color image segmentation in the case of plates in accordance with body color, positioning accuracy decreased. On the basis of in-depth study and analysis of the above algorithms, this paper proposes a new method of license plate location based on simplified PCNN and comprehensive feature. The detailed flow chart is shown as in Fig. 1.

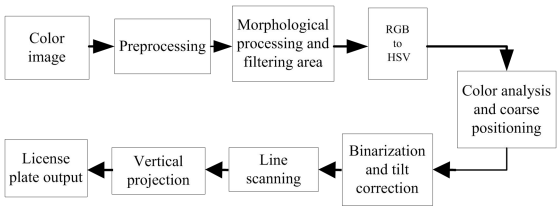


Figure 1. The flow chart of license plate location

II. SIMPLIFIED PCNN MODEL

In the early 1990s, Elkhorn brought forward PCNN models with biological background which are based on experimental observations of synchronous pulse bursts in the cat and monkey visual cortex [8]. Since pixel in license plate with gray similarity and spatial proximity, and PCNN can be grouped in such a pixel, so it is very suitable for the license plate location [9]. In this paper, we use the simplified PCNN model and the mathematical equations are as follows.

$$F_{ij}[n] = S_{ij} \tag{1}$$

$$L_{ij}[n] = \sum W_{ijkl} Y_{ij}[n-1] \tag{2}$$

$$U_{ij}[n] = F_{ij}[n](1 + \beta L_{ij}[n]) \tag{3}$$

$$Y_{ij}[n] = \begin{cases} 1 & \text{if } U_{ij}[n] > \theta_{ij}[n-1] \\ 0 & otherwise \end{cases} \tag{4}$$

$$\theta_{ij}[n] = \exp(-a_\theta)\theta_{ij}[n-1] + V_\theta Y_{ij}[n] \tag{5}$$

In the above formula, S_{ij} represent input incentives and the incentive of the neurons denotes the pixel values of (x, y) in image processing. The feeding input and linking input use F_{ij} and L_{ij} to denotes, respectively, and both of them jointly determine the value of PCNN model neuron's internal activities U_{ij} . And W represent internal connection matrix. Where β is linking coefficient and Y_{ij} represents the outputs of the neurons and only have two values: 0 and 1. Where θ_{ij} denotes the dynamic threshold of the neurons, when $U_{ij} > \theta_{ij}$, $Y_{ij} = 1$ otherwise $Y_{ij} = 0$, so each iteration of

PCNN output is a binary image. The threshold of neurons for attenuation according to (5), and attenuation coefficient is α_θ and V_θ is constant amplitude.

III. PRE-PROCESSING

A. Gray-scale conversion

In order to reduce the computation, converting color images to gray images. This paper uses the weighted average method for gray-scale image processing. The conversion formula is denoted by

$$f(x,y)=0.30*R(x,y)+0.59*G(x,y)+0.11*B(x,y) \quad (6)$$

In the formula, $f(x,y)$ represents the gray value, $R(x,y)$, $G(x,y)$, $B(x,y)$ stand for the original true-color image of the red, green and blue components, respectively.

B. Top-hat transform

Top-hat transform is one of the definitions on the gray image morphological operation. Function $f(x,y)$ represent the gray image, s denotes the structure operator, therefore, the top-hat transform of the $f(x,y)$ is denoted by

$$h(x,y)=f(x,y)-(f(x,y)\circ s) \quad (7)$$

In (7), $\circ$ represent opening operation. Choosing the structural elements which is slightly larger than the license plate to do open operation for the original image, and the non-uniform background is obtained. Then, using the original image pixel value minus the result of open operation to remove the non-uniform background for enhances the effect of the license plate area.

C. Edge detection of gray image

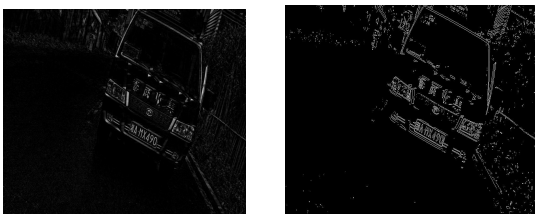
The background color, edge color and character color of our license plate is different from each other, which determines the license plate area contains lots of edge information. Therefore, edge detection operator can be used to highlight the image of license plate region. By comparing the edge detection operators found that Sobel operator can suppress noise and detect the horizontal and vertical edges. Since the characters of car license plate area is most obvious in the vertical direction, so this paper selected the Sobel operator to detect the image edge information.

D. The simulation results

Experimental images used in this paper are 951×634 pixel color images, the original image and the gray image are shown in Fig. 2 (a) and (b).

(a) Original image (b) Gray image

Figure 2. Gray-scale transformation



(a) Top-hat transform image (b) Sobel edge detection image

Figure 3. Image enhancement

Using top-hat transform and Sobel operator for gray enhance and gray image edge detection. After top-hat transform and Sobel edge detection, the images are shown in Fig. 3 (a) and (b), respectively.

IV. LICENSE PLATE LOCATION ALGORITHM

A. Mathematical morphological operation and regional filtering

Combined with the prior knowledge of the license plate area, we can carries on mathematical morphology operation of Fig. 3(b), make the license plate region and other background region separated into separate areas [10]. Then, we can use the structural features to filter the connected region.

License plate area has a certain value and the very small area is seen as background interference to eliminate it. In this paper, we remove the area smaller than 300 connected region. License plate aspect ratio within a certain range, in order to prevent the license plate tilt affect the plate aspect ratio and minimize the leakage area, we choose the aspect ratio range of [1,6]. The filtered candidate region is shown in Fig. 4.

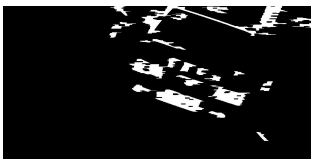


Figure 4. Filtered area

B. Color space selection

According to the coordinate of each connected region rectangle corner in Fig. 4, we can extract the color image connected region from the original image. Because the car image is generally RGB image, but the three components R, G, B in the RGB model are sensitive to the intensity of light, and even if the two colors are very similar, their R, G, B values may also have large gaps, so color segmentation in RGB space is not appropriate. While the HSV color model using hue(H), saturation(S) and value(V) to describes the color, which are closer to human's experience and perception of color, and can easily by adjusting the values of these three parameters to achieve color segmentation, this paper choose the color segmentation based on HSV model. In the three components of RGB, setting the maximum MAX and minimum MIN. RGB to HSV conversion formula is as follows.

$$V=MAX \quad (8)$$

$$S = \begin{cases} 0 & V = 0 \\ \dfrac{MAX - MIN}{MAX} & V \neq 0 \end{cases} \tag{9}$$

$$H = \begin{cases} \dfrac{G - B}{MAX - MIN} \times 60^\circ & , \quad R = MAX \\ \left(2 + \dfrac{B - R}{MAX - MIN}\right) \times 60^\circ & , \quad G = MAX \\ \left(4 + \dfrac{R - G}{MAX - MIN}\right) \times 60^\circ & , \quad B = MAX \end{cases} \tag{10}$$

C. Color analysis and coarse location of license plate

The type of license plate in our country are mainly classified into blue bottom white word, yellow bottom black word, white bottom black word and black bottom white word. Through the experimental test statistics obtained the range of plate color in the HSV color space as shown in table I.

TABLE I. License plate color range in HSV color space

Color	*Blue*	*Yellow*	*White*	*Black*
H	[180,270]	[25,55]	—	—
S	[0.35,1]	[0.35,1]	[0,0.1]	—
V	[0.3,1]	[0.3,1]	[0.7,1]	[0,0.3]

With blue and white as an example, color image in each candidate region is first transferred from RGB space into HSV space, then traverse the transformed values of each pixel in the image, setting the value meet the blue threshold interval for 1, otherwise for 0. Through the color features of the plate, we can further filter the candidate area shown in Fig. 4, the steps are as follows:

a) Statistics of blue pixels in each candidate area, filtering out the significantly area that is less than the plate background pixel area, this paper filter out blue pixel area of less than 200.

b) There is a fixed license plate color collocation and the color exchange rate in horizontal direction is greater than 5. Taking the center location of the remaining candidate region in the horizontal direction after filtered and scanning 5 lines up and down, and then getting the average of color exchange in the 10 lines, filter out the area that the average number of color exchange is less than 5.

c) Due to the ratio of the background pixels and the character pixels of the license plate area is greater than 1, through statistic the number of white pixels in each candidate region, we can filter out the area that the ratio of blue pixels and white pixels is less than 1.

The color filter steps are sequentially performed, after each step we should check the remaining number of the candidate area, when there is only one area then the rest is no longer filtered. Through repeated experiments and analysis, after the color filter in the candidate region, in general the remaining area is the corresponding area of license plate. In order to enhance the robustness of the algorithm and the ability to deal with the complex background, when the color analysis still remaining more than one region, we can compared the remaining candidate regions of the aspect ratio with standard license plate aspect ratio of LW, the region closes to the plate prior to do the next line scanning operation, to determine whether the region contains the license plate, and repeat until obtaining the license plate area. China's automobile license plate standard outline size is 440*140 mm, the aspect ratio is 3.14, so choose LW=3.14. The coarse position results of the license plate as shown in Fig. 5(a).

D. License plate binatization and tilt correction

Using the simplify PCNN model for binarization of license plate coarse locating results. PCNN operation needs to design parameters in advance. By the analysis of experimental results for many times, when β =0.1, α_θ =0.1, W is [0.707 1 0.707; 1 0 1; 0.707 1 0.707], V_θ =10, and the number of iterations is set to 10, the binarization effect of license plate is ideal, as shown in Fig. 5 (b).

(a) License plate coarse location (b) License plate binarization

Figure 5. License plate binarization

Because of shooting angle problem, it may cause the tilt of license plate image. Considering the tilt plate is not conducive to subsequent line scan analysis and character segmentation, so make tilt correction of license plate. The common license plate tilt correction methods mainly include Radon algorithm and Hough transform method. This paper selects the Radon algorithm for license plate tilt correction [11], and the experiment result is shown in Fig. 6.

Figure 6. Tilt corrected license plate

E. License plate precise positioning

Step 1: Horizontal positioning based on line scan.

Fig. 6 shows that the coarse location determine approximate location of license plate, but still has lots of non-character interference region, such as up and down, left and right borders and rivet, their presence will have an unfavorable influence on the character segmentation of license plate, so we must remove these areas. The binarized license plate character area has the characteristics of the grain of black and white pixels jump, and there are seven consecutive characters, each character will appear at least two times jump, so characters area continuous jump number per line will be more than the other characters. The upper and lower boundaries of the license plate characters can be determined by scanning the coarse location area. The detailed descriptions are as follows.

1) From top to bottom, left to right scan the rough location of lines in the region, and set a Sum[j] array to record the number of jump (j corresponds to the corresponding line numbers), the pixel value from 0 to 1 or from 1 to 0 as a jump, each jump appear in this line, Sum[j] plus 1.

2) Set a variable Step to record the number of jumps, since there are seven characters in the license plate area, the value of selected Step is 14, during the scanning process, if Sum[j] is

less than Step, then j++, otherwise it will be j for recording as the upper boundary. Then continue to scan, finding Sum[j] which is less than the Step, and the j-1 record for the lower boundary of the license plate.

3) At the same time, the upper and lower boundary value difference absolute value must be greater than 10, otherwise, repeat step *1) , 2)* from the lower boundary value plus 1.

Finding the license plate characters upper and lower boundaries through the above steps, experimental results are shown in Fig. 7.

Figure 7. Line scanned license plate image

Step 2: Vertical positioning based on vertical projection.

Through line scan we can precisely locate the license plate upper and lower boundary, but left and right boundary still have any interference, this paper use the vertical projection combined with threshold method to remove the interference. Specific steps are as follows.

1) Vertical projection of the binary image, and save the white pixel number of each column to an array Count[i].

2) Setting a threshold T, then find the first value large than T in the array Count[i] from left to right, and record the corresponding column numbers i. In the array Count[i], if there has continuous number T1 large than T, i that is the coordinate value of the corresponding left border. After finding the left border, we can find the right boundary location of the license plate from right to left in the same way, take T1 = 10, T = 2.

Through the above method, we can remove the interference on both sides of the plate region, and get the precise license plate area, as shown in Fig. 8.

Figure 8. Accurate location of the license plate

F. Experimental results and analysis

In order to verify the algorithm's accuracy, this paper has collected 200 pieces of license plate images from different weather conditions, backgrounds and natural conditions, and tested in MATLAB R2013b, the positioning accuracy rate is up to 98%. The images of the license plate failed to locate is mainly due to pollution and obscured, which led to the texture and color features of the license plate are not obvious.The algorithm proposed in this paper and algorithm in [7] is compared, the experimental results are shown in table II.

TABLE II. Location algorithms comparison

Location algorithms	***Number of test images***	***Accuracy rate***
The algorithm in this paper	200	98%
License plate location in RGB color space[7]	200	96%

We can see from table II, this paper has proposed an algorithm with high positioning accuracy. Localization algorithm in [7] extract the feature of image by using the color features of license plate, then doing the binarization and morphological processing of image and doing region label of the connected regions as well. After that, we can get the license plate area by detecting the rule of license plate characters. But the license plate and car body will adhesion when the car body's color likes the license plate's color, which reduces positioning accuracy. In this paper, we extracted the candidate area by using edge detection and morphological processing, and then do color analysis. Finally, using scanning and vertical projection to get the accurately location of license plate. In this way, we can get accurate positioning even if the car's body color is similar to the license plate color.

V. CONCLUSION

Aiming at the problem of vehicle license plate location in complex background, this paper proposed a new method of license plate location based on simplified PCNN and comprehensive feature. The algorithm makes full use of the texture, shape, color and other characteristics of the license plate, has higher positioning accuracy. Due to the conversion from RGB color space to HSV space will affect positioning speed, the algorithm only do color space transformation in the candidate regions which extracted by the license plate structure features, reduces the time complexity of the algorithm. The algorithm firstly analyze the texture and structure of license plate image, then make color analysis of license plate, and using line scan and vertical projection to get the accurate location of the license plate, so when the car body with license plate similar color, we can still accurately positioning. Finally, the experimental results show that the positioning accuracy of this algorithm as high as 98%, and is benefit to the subsequent character recognition.

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