Detecting License Plate Based on Top-hat Transform and Wavelet Transform

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Abstract

In a vehicle license plate identification system, plate region detection is the key step before the final recognition. This paper presents a license plate detection algorithm from complex background based on top-hat transform and wavelet transform. First, the vertical gradient of gray image is calculated and the region of license plate is standed out by using top-hat transformation. Then the horizontal projection of gradient variance is obtained and horizontal candidates are located by using threshold. Multiresolution feature of candidates are extracted by using wavelet transformation in the following. Finally, accurate vertical position of license plate is detected and license plate is extracted from image. In order to show the effectiveness of the proposed method, experiments have been conducted on 360 images taken from various scenes and different conditions. The algorithm can quickly and correctly detect the region of license plate and the license plate detecting rate of success is 98. 61%.

1. Introduction

With the development of Intelligent Transport Systems (ITS), automatic license plate recognition (LPR) plays an important role in numerous applications in reality. And how to find the license plate region from complex scenes is the key component of LPR, for which directly affects the system's overall performance. A large number of scholars have carried on the research and development of this technology recently, and a number of techniques have been proposed, such as the methods base on edge extraction[1], Hough transform[9], color feature, and histogram analysis[8]. But most previous works have in some way restricted their working conditions, such as limiting them to indoor scenes, stationary backgrounds, fixed illumination, prescribed driveways or limited vehicle speeds [4-7]. In this paper, as few constraints as possible on the working environment are considered.

This article put forward a method about the automobile license plate automatic detecting that based on top-hat transform and wavelet transform. And experiments indicate that the algorithm is quick and efficient for most scenes.

The rest of the paper is organized as follows: section 2 discusses about the features of license plate's region, section 3 introduces the algorithm in detail, section 4 shows the experimental results and finally section 5 concludes the paper with references.

2. Analysis the feature of Chinese license plate's region

Based on the Standard of GA36-92 about motor automobile license plate's number which laid down by People's Republic of China in 1992, the shape of automobile license plate generally is the rectangle, and the length-width ratio is limited to several kinds, such as the outline size of little car's license plate is 440*140(mm). Its characters are arranged as: x1 x2 • x3 x4 x5 x6 x7, x1 is the Chinese character, and x2 is

English letter, and x3 is English letter or Arabic numeral, and x4 x5 x6 x7 are the Arabic numerals. The width and height of every word are 45mm and 90mm respectively. The wide of the interval symbol is 10mm, and every unit interval's wide is 12mm. Furthermore the distance from symbol to top border or bottom border is 15.5mm, and the length from first symbol to left border or from last character to right border is 25mm.

3. License plate detection

For most of the images of license plate acquired from real environments are color images, we have to change them into gray ones before processing. The equation is shown in Eq.1

$$f(i,j) = 0.114 * A(i,j,1) + 0.587 * A(i,j,2) + 0.299 * A(i,j,3) \quad (1)$$

where, f(i,j) is the array of gray image, A(i,j,1), A(i,j,2),A(i,j,3) are the R,G,B value of original image respectively. In the section following, we will introduce our algorithm step by step.

3.1 Acquire vertical gradient from gray image

From part 2, we have the knowledge that most license plates are composed of two colors. So gray of the character pixel and the background pixel are different. We can make use of this feature of the license plate to detect its region. We first calculate the average gradient variance and compare each other. The bigger intense of variations represents the position of license plate region. So we can roughly locate the horizontal position candidate of license plate from the gradient value. We can calculate vertical gradient using Eq.2.

$$g_v(i,j) = |f(i,j+1) - f(i,j)| \quad (2)$$

3.2 Top-hat transformation of The vertical gradient

Mathematical morphology [3][4] is an non-linear filter, with the function of restraining noises, extracting features and segmenting images etc. Its characteristic is that it can decompose complex figure and extract the meaning figures. Mathematical morphology's basic arithmetics are erosion and dilation. Their equations are shown in Eq.3 and Eq.4 respectively.

$$X = A \Theta B = \{X : B + X \subset A\} \quad (3)$$
$$X = A \oplus B = \{X : (-B + X) \cap A \neq \Phi\} \quad (4)$$

Aggregate A is eroded by structure B in Eq.3 and Aggregate A is dilated by structure B in Eq.4.The erosion arithmetic and dilation arithmetic could not be resumed. The two operations can conform the open and close arithmetic. Their equations are shown in Eq.5 and Eq.6 respectively

$$A \circ B = (A \Theta B) \oplus B \quad (5)$$

$$A \bullet B = (A \oplus B) \Theta B \quad (6)$$

Structure B open Aggregate A in Eq.5 and structure B close Aggregate A in Eq.6. Open arithmetic can eliminate little objects, and separate objects at fine places, smooth boundary of big objects. Close arithmetic can fill in little holes of objects, and connect two neighborhood objects, smooth boundary of objects. Top-hat transformation is one of Mathematical morphologic transformations. It is efficient in searching black pixels in white background or white pixels in black background. The equation of top-hat transformation is shown in Eq.7.

$$HAT(A) = A - (A \circ B) \quad (7)$$

From Eq.7, we can see that the top-hat transformation of Aggregate A is that Aggregate A subtract the result of structure B open Aggregate A. In our arithmetic, Aggregate A is vertical gradient $g_v(i,j)$, and structure B is a 3*3 matrix.The gray image of original image is shown in Fig.1 and it's top-hat transformation is shown in Fig.2.

Fig.1 the gray image of original image

Fig.2 the image after top-hat transformation

3.3 Get horizontal candidates

From step 2, we can see that the region with bigger value of vertical gradient can roughly represent the region of license plate. So the license plate region tends to have a big value for horizontal projection of vertical gradient variance. According to this feature of license plate, we calculate the horizontal projection of gradient variance using Eq.8.

$$T_H(i) = \sum_{j=1}^{n} g_v(i, j) \tag{8}$$

For there are many burrs in the figure of horizontal projection, we introduce Gauss filter with the purpose of getting rid of these burrs. For the curve is discrete, we often use Eq.9 to filter the image.

$$T'_H(i) = \frac{1}{k}\left\{T_H(i) + \sum_{j=1}^{w}\begin{bmatrix} T_H(i-j)h(j,\sigma) + \\ T_H(i+j)h(j,\sigma) \end{bmatrix}\right\} \tag{9}$$

where $h(j,\sigma) = e^{-(j\sigma)^2/2}$, $k = 2\sum_{j=1}^{w} h(j,\sigma) + 1$,

$T_H(i)$ represents the original projection value, $T'_H(i)$ shows the filtered projection value, and i changes from 1 to m. w is the width of the smoothness region, $h(j,\sigma)$ is the Gauss filter and σ represents the parameter of Gauss filter. After many experiments, the practicable values of Gauss filter parameters have been concluded. In our algorithm, w = 8 and σ =0.05. And the curve after filtering is shown in Fig.3.

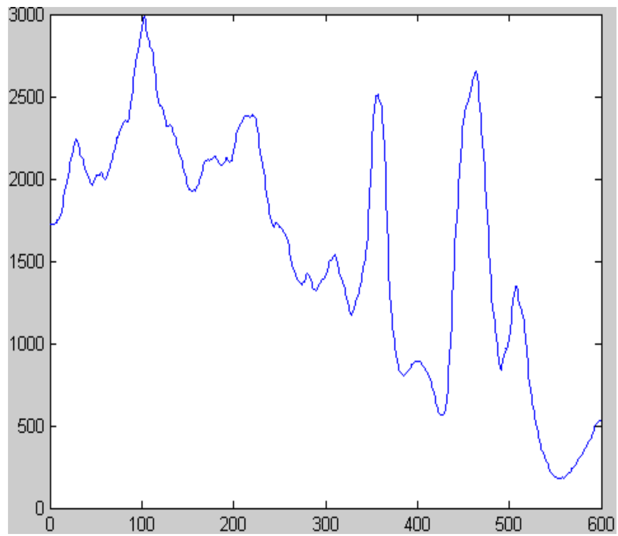

Fig.3 The horizontal projection after filtering

For the region with bigger value of horizontal projection can roughly represent the region of license plate, we can use a threshold to locate the candidates of the horizontal position of the license plate. The threshold T is calculated by Eq.10 with aver represents the average of the filtered projection value $T'_H(i)$ and t represents weight parameter.

$$T = t * aver \tag{10}$$

In our algorithm, after experiments, t =1.1. If $T'_H(i)$ is larger than or equal to T, we set a mark on it and let the value of stack(1,i) be 1, else we let the value of stack(1,i) be 0. The mark of stack is shown in Fig.4.

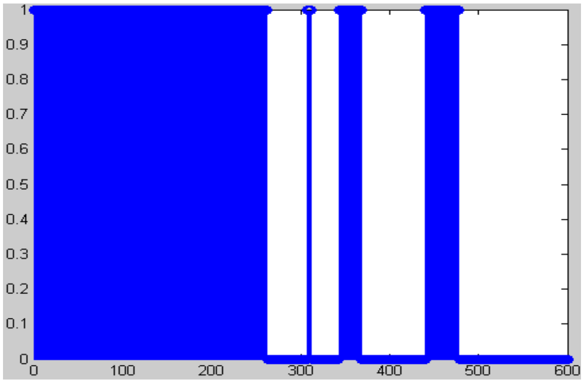

Fig.4 The mark of stack

From Fig.4, we can see that in stack, the continuous mark with 1s represents the candidate of the horizontal position of license plate. Then we use some rules to amalgamate some regions if it is possible and get rid of some regions with too wide or too narrow width. And the left regions are the real candidates. Finally, we duplicate the region of license plate from original image as license plate's candidates. The result is shown as Fig.5.

Fig.5 The candidate of original image

3.4 Wavelet transformation of candidates

The wavelet transfor[10][11] gives us an invariant interpretation of license plate image at different physical levels. It presents a multiresolution analysis in form of coefficient matrices. Because the details of license plate image at different resolutions generally characterize different physical structures of the license plate, we can make use of these coefficients obtained from wavelet transform in license plate detection. In this paper, we use Haar transform to execute wavelet transform in two dimensions to extract multiresolution feature, and its equation is shown as follows:

$$W_{\varphi}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\varphi_{j_0,m,n}(x,y) \tag{11}$$

$$W_{\psi}^{i}(j_0,m,n)=\frac{1}{\sqrt{MN}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)\psi_{j_0,m,n}^{i}(x,y) \tag{12}$$

where $\varphi_{j_0,m,n}(x,y)=2^{j/2}\varphi(2^{j}x-m,2^{j}y-n)$,

$$\psi_{j_0,m,n}^{i}(x,y)=2^{j/2}\psi^{i}(2^{j}x-m,2^{j}y-n)$$

The $W_{\varphi}(j_0,m,n)$ coefficients define an approximation of $f(x,y)$ at scaling j_0 . the $W_{\psi}^{i}(j_0,m,n)$ coefficients add horizontal, vertical and diagonal details for scales $j\geq j_0$. $\varphi_{j,m,n}(x,y)$ represents scaling function, $\psi_{j,m,n}^{i}(x,y)$ is three two-dimensional wavelets. And $i=\{H,V,D\}$. For discrete image processing, we always execute Mallat algorithm to get high frequency information. And the flowchart of the algorithm is shown in Fig.6.

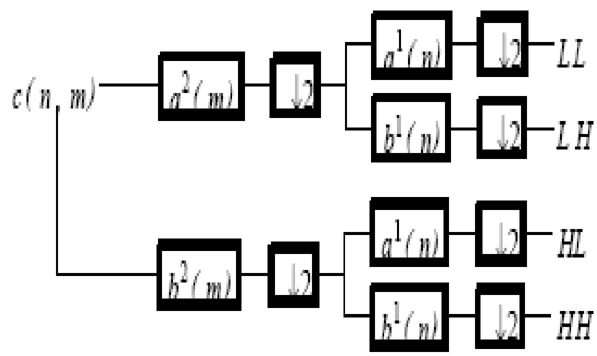

Fig.6 The flowchart of wavelet transform

We can see from Fig.6 that after wavelet transformation of the candidate four sub-images will be obtained: LL,LH,HL and HH. LL shows the lowpass-filtered original image or approximation sub-image. LH express characteristics contained in vertical directional. HL contains horizontal directional characteristics and catercorner characteristics is shown in HH. Obviously, these four bands can represent the feature of license plate region. In order to give prominence to license plate region, the pixel value of every bands of original image is normalized 0~255.

3.5 Find accurate vertical position of license plate and extract license plate from image

From the former step, we obtain four bands of original image and the bands except LL band represent the high frequency feature of original image. So we calculate the first differences of these bands to stand out the gray-value variety of the license plate region. And then we add the differences of three bands together. The equation of calculating difference is shown in Eq.13 with Dif represents the overall difference of these bands. And the result is shown in Fig.7.

$$\begin{aligned} Dif(i,j) = &|LH(i,j+1) - LH(i,j)| + \\ &|HL(i,j+1) - HL(i,j)| + |HH(i,j+1) - HH(i,j)| \end{aligned} \tag{13}$$

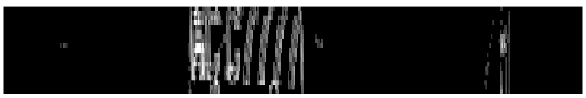

Fig.7 The overall difference of three bands

In Fig.7, we can see that the region of license plate is with much higher gray-values. Based on this feature, we can ascertain the vertical position of license plate.

At first, we carry on a column search for Fig.5 which is an image with mm rows and nn columns. The column search is carried from 3 to nn-2, and six columns is a checking region. We calculate the density of this region. If the density is bigger than the threshold, we can consider the column be a column of the license plate region and set a mark on it. Then we will get the license plate region by searching for the longest continuous mark. If the requirement of the license plate scale is missed, we carry on further search until the column positions satisfy all of our requests. Finally, we get the row positions of the license plate region by carrying on a row search in the middle of column position.

From above steps, we can get the row and column position of the license plate. In order to make the location more accurately, we use some rules to adjust the row and column position and then we extract the accurate license plate image from original image. The extracted license plate image is shown in Fig.8.

Fig.8 The accurate license plate region

4. Experimental result

360 images taken by CCD camera from various scenes and under different conditions, including diverse angles, different lightening conditions and the dynamic conditions, were employed in the experiment. The size of the images is 600*450. The result of the experiment is shown in table 1.

Table.1 Result of the license plate location algorithm applied on the real image database

Total images	horizontal position detecting	vertical position locating	failure
360	356	355	5
Percent (%)	98.89%	98.61%	1.39%

Because of the existence of too many other text blocks and weak gradient information from the plate area of some license plates, 5 images in our experiment failed. The success rate is 98.61%.

5. Conclusion

A robust approach of extracting license plate from original image is presented in this paper. The Five-step approach is designed to deal with images taken under various real world circumstances. Based on top-hat transform and wavelet transform, we can extract license plate region accurately.

From the result of the experiment, we can see the proposed approach is promising. But there are some images failed, so we can carry on further research using the feedback information of the recognition of license plate's characters in order to acquire more favorable results.

6. References

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