Hybrid Method for License Plate Detection from Natural Scene Images

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***Abstract*—License plate detection is a key part in vehicle license plate recognition system. In this paper, we present a hybrid method for license plate detection from natural scene images for the all-day traffic surveillance environment. The proposed method includes two stages: rough detection and accurate detection. Coarse detection stage based on color edge and morphology can help finding the region of interest quickly; Accurate detection stage based on HOG and SVM accurately detect the vehicle license plate. The effectiveness of the proposed method has been proven by the experimental results on a large database of images.**

Keywords—license plate detection; color pairs; mathematical morphology; HOG feature; SVM.

I. INTRODUCTION

With the rapid development of traffic and the wide use of vehicle, the intelligent transportation system (ITS)has been developed and applied all over the world, and license plate recognition system as an important part of the ITS also become an indispensable part of human life. The license plate recognition system [1] mainly consists of three parts: license plate detection (LPD), character segmentation and character recognition. Obviously the first step LPD is the key and difficult part of the system.

At present, the LPD research mainly includes four methods. (1) The method based on color segmentation [2]. This method detect license plate by extracting color information. In order to reduce the effect of illumination, generally first convert the image from RGB color space to HSV color space, then according to the threshold separate license plate from background. The method accuracy is higher, but when the license plate and background color is similarity, the accuracy will be declined. (2) The method based on edge detection and mathematical morphology [3].The method first extract edge information, then use morphology method and statistics edge number to locate license plate. This method is simple, rapid, and accuracy is high, but it is also sensitive to the other edge, so the error rate of this method is higher. (3) The method based on Wavelet Transform [4]. In this method, first converts the image to index image, and we can get the wavelet coefficients of different sub-hand by wavelet transform. According to the character that large amplitude and high density of wavelet coefficients in license plate area, we can locate license plate. The accuracy of this method is high when the noise is small, but detection speed is slow, when noise is big error detection rate will increased. (4) The method based on machine learning [5]. The method use neural network method, design a sliding window move on gray image: The image as the input of neural network, such as three layer BP neural network, the number of input neurons is sliding window size while the output neurons is 1. When the output is close to 1/2 indicates the area belongs to license plate area, when the output is close to -1/2, it is not a license plate area. This method has High location accuracy, but scan on the whole image, computational cost is very larger, don't conform to the requirements of the real-time.

In order to take into account the license plate detection speed and detection accuracy, this paper proposes a detection method from coarse detection to accurate detection. First we use color information and edge information to detect plate interest regions quickly. Accurate detection phase take the histogram of oriented gradient (HOG) feature and support vector machine (SVM) to verification candidate regions, and accurate location license plate.

The following paragraphs describe in detail each step and the obtained results. Fig. 1 shows the proposed LPD process.

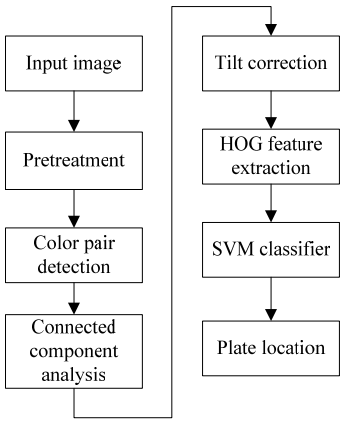


Fig. 1. The flow chart of license plate detection

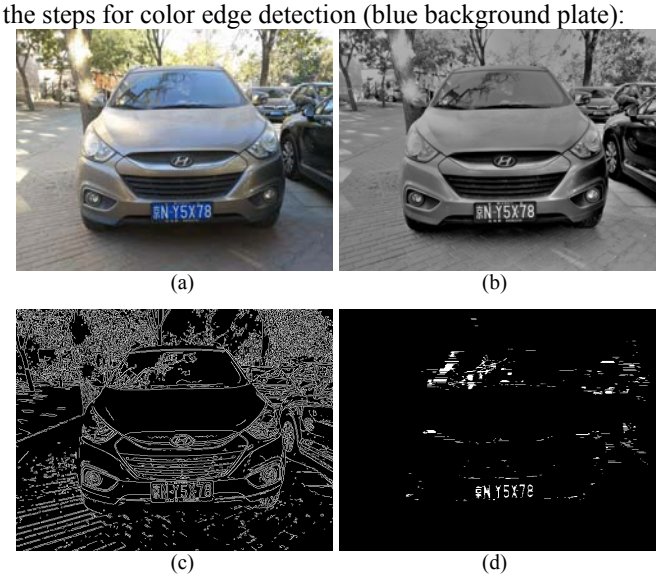
II. LICENSE PLATE DETECTION

A. Rough detection

There are some obvious characteristics of Chinese license plate, such as color features and texture features. A fixed color

collocation of license plate is a most important characteristic of color features. It mainly includes blue and white, yellow and black, white and black and so on. So we extract the color pairs (blue-white) to determine the license plate candidate area. Coarse detection stage consists of color pair point detection [6], morphology processing, connected domain analysis three parts.

1) Color pair detection: In order to reduce the license plate detection time, gray-scale images processing needed to remove as far as possible the background that does not contain license plate region. First the color image will be transformed to gray-scale image, then use sobel operator which is easy and quick to extract the edge. License plate has dense texture and the color between characters and background is fixed, so we detect the color pairs(blue-white pairs) on the color image according to the edge image. Because we only search color pairs in the edge position, it greatly shorten the processing time. At the same time, to highlight the texture of characters on the license plate better we connect the two color pairs if the distance between them if less than a threshold T. Fig. 2 shows the steps for color edge detection (blue background plate):



(a) (b) (c) (d)

Fig. 2. (a) Source image (b) Gray image (c) Edge image (d) Color pair image

2) Morphological processing: In order to get connected region of the license plate candidate area, after get the binary image, We use rectangular structure element for closing operation. Because the method depends on color threshold, there will be a small noise inevitably that may affect the last results, we use morphological open operation to reduce the noise.

a) Closing operation: We use closing operation to connect neighboring objects based on the binary color edge image. The closing of A by B is defined as the process that dilation of A by B then erosion of the result by B:

$$A \bullet B = (A \oplus B) \Theta B \tag{1}$$

Where $\oplus$ and Θ denote dilation and erosion, B denote the structure element (SE). After applying closing operation, the result image achieved in the Fig. 3(a).

b) Opening operation: We use opening operation to remove noises based on the closing image in the Fig. 3(a). The opening of A by B is defined as the process that erosion of A by B then dilation of the result by B:

$$A \circ B = (A \Theta B) \oplus B \tag{2}$$

After applying opening operation, the result is achieved in the Fig. 3(b).

(a) (b)

Fig. 3. (a) closing operation (b) opening operation.

3) Connected component analysis(CCA): After applying morphology operation, the following steps that based on connected component analysis will get the candidate regions. With the important information from the CCA, some features of the region, such as the aspect ratio(R), the area(A), the width W, the height H and the density(D) of region are applied:

$$D = \frac{A}{W \times H} \tag{3}$$

When the region meets these three conditions: A>50, 2<R<5, D>0.4, it will be preserved, otherwise remove the region.

B. Accurate detection

Due to the effects such as illumination and angle, Accurate location license plate in nature scenes is always a difficult problem. In order to achieve the accurate location of vehicle license plate, this paper proposes a method based on feature extraction and classifier to guarantee the completeness of the license plate. In order to get rid of the angle interference, before the precise location we need to correct inclined plate region.

1) Calculation inclined angle: Because the influence of vertical direction tilt is small, we only carry on the research of horizontal tilt correction. The main research contains the following methods: (1) Hough transformation method: We find the longest line or bounding rectangle by Hough transform in the candidate region to get the tilt angle. (2) Rotating projection [7]: Through rotating license plate image, the binary image projection to the longitudinal axis, then find out the peak width W of each rotation projection and compare W in different rotation angle to get the tilt angle. (3) Principal component analysis (PCA) [8]: We will carry out the principal component direction which is tilt angle by analysis principal

component of edge image. (4) Formula derivation [9]: This method is based on the principle of that the variance of edge point projection image is smallest when the license plate is not tilted. Then we will get the tilt angle through the closed expression that is derived according to minimum variance projection.

After get the inclined angle, we use bilinear interpolation method for correction. In this paper, we use 40 images to do tilt correction experiment. The results show that using rotating variance formula derivation method has good effect on license plate tilt correction. Some samples are presented in Fig. 4.

Fig. 4. Tilt correction

2) Accurate detection: In accurate detection stage, a method based on Histogram of oriented gradient (HOG) feature and SVM classifier is presented. Figure 5 shows the detail detection process.

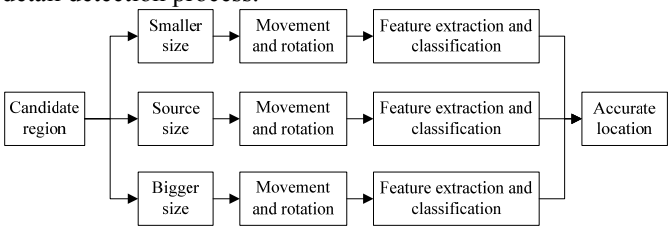


Fig. 5. The flow chart of accurate detection

a) HOG feature: Histogram of oriented gradient (HOG) is a feature descriptor by computational and statistical local area gradient direction histogram. According to HOG feature, the image is divided into many small connected regions, and each connected area as a cell, then statistics the histogram of oriented gradient by each pixel in cells. Finally, the results form a feature descriptor. HOG feature has been widely applied in word recognition [10], traffic sign recognition [11]. License plate accurate location depends on its characteristic that contains the text, so we use HOG features to locate license plate.

After get the plate candidate region, we need to compute the HOG feature of the region and its neighbor region. It main includes five parts: (1) Image preprocess. Gray normalized processing can reduce the shadow of local area and the effects of illumination change; (2) Calculating the gradient of each pixel in image. As shown in the following formula, first we use operator [-1, 0, 1] and $[-1, 0, 1]^T$ to calculate the horizontal gradient $G_x(x, y)$ and vertical gradient $G_y(x, y)$ of each pixel, then calculate the gradient G(x, y) and the direction α(x, y);

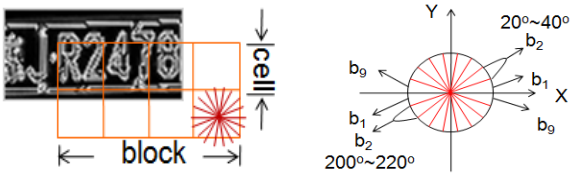
$$G_x(x,y) = F(x+1,y) - F(x-1,y) \quad (4)$$

$$G_y(x,y) = F(x,y+1) - F(x,y-1) \quad (5)$$

$$G(x,y) = \sqrt{G_x(x,y)^2 + G_y(x,y)^2} \quad (6)$$

$$\alpha(x,y) = \tan^{-1}\left(\frac{G_y(x,y)}{G_x(x,y)}\right) \quad (7)$$

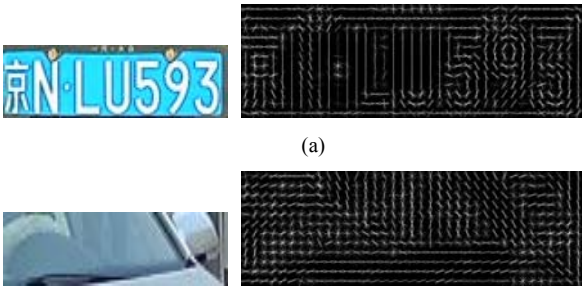
(3) Build histogram of oriented gradient for each cell unit. In this paper, the image is divided into a series of cells. Each cell is the size of 7*6 pixels, the gradient direction 180 degrees of each cell can be divided into nine direction, and compute the weighted projection in gradient direction histogram of each pixel in cells. Finally we can get the 9 dimension feature vectors of the cell, as shown in figure. 6 (b); (4) The cells are combined into larger block, and histogram of oriented gradient in every block is normalized, the normalized can further compress the light, shadow and edge. The feature vectors of all cells within a block are combined in series to get the HOG features of the block, as shown in figure. 6 (a). Because the cells are overlap, the feature of each cell will appear repeatedly at the end of results. The normalization block descriptor is called a HOG descriptor; (5) Collecting HOG features of all overlapping blocks in detection space to combine into the feature vector. In this paper, our feature vector dimension is 1620.



(a) (b)

Fig. 6. (a) A block include 4*2 cells
(b)180 degrees devided into nine direction

Fig. 7 shows the views of license plate area and the interference area. To contrast, HOG feature can effectively show the contour and texture feature of license plate area.



(a)

(b)

Fig. 7. (a) The HOG feature view of license plate area
(b) The HOG feature view of interference area

b) Support Vector Machine (SVM) classifier and detection: SVM is first put forward by Cortes and Vapink and it is based on Statistical Learning Theory. It is a method that concludes the algorithm of finding priority hyper plane to a convex programming problem. The final decision function of SVM is only determined by a few support vectors, so we just need train key samples and eliminate redundant samples. Based on these, SVM is a simple and robustness method. In

this paper, we use HOG feature and Liner SVM classifier to detect the license plate.

Accurate detection stage, in order to promote detection speed, according to the size of license plate candidate region we design a three scale window scanning method to locate license plate. In each scale image, we get some corresponds images through movement and small angle rotation around the license plate region. Then we calculate the HOG features of each region and classification by SVM classifier. At last, the largest return weight value that correspond area is the license plate.

As shown in Figure. 8, the red box represents the results of the coarse positioning, and green box represents accurate location. The results show the proposed detection algorithm has a good effect.

Fig. 8. Accurate detection

III. EXPERIMENT RESULTS

To evaluate the proposed method, 412 images are collected in different views and illuminations from natural environment as the database. Image capturing device is Cannon EOS 600 D, all images are captured under autofocus mode. Image size is adjusted to 640 * 480. Experiment platform is a Lenovo desktop with 2.66GHz processor frequency and 2GB memory.

A. *License plate detection*

In order to verify the effectiveness of the proposed detection method, three methods are used to do the contrast experiment: (1) The first method directly uses HOG feature and SVM classifier to detect license plate on the source image. (2) The second method through vertical edge feature to determine plate candidate area, then on the basis of the candidate region to extract HOG feature and classification. (3) The third method firstly extract image edge information, then search license plate color edge points to get the candidate regions, at last, use HOG feature and SVM classifier to verify the plate region and accurate location. TABLE I shows the results.

The first method has a higher detection rate, but it is computational cost, the speed is very slow, do not meet the requirements of real-time. The second method uses vertical edges to find candidate region, then use classifier to locate license plate, so it has a higher detection rate while the detection speed has a good promotion. According to the image edge information, the third method detects color edge regions in the corresponding position of the edge points to locate the license plate area. Due to the fixed color collocation feature of the license plate, the interference area is less. So the third method greatly improve the detection speed, at the same time has lower error detection rate and high location accuracy. So in this paper we use the third method as our detection method.

TABLE I. THREE DETECTION METHODS

Algorithm	Detection results		
	Recall	***Precision***	***Average time***
First method	98.54%	90.05%	3200ms
Second method	98.06%	87.38%	290ms
Proposed	98.06%	93.69%	310ms

B. *Accurate detection*

This section we use five methods to solve the problem of inclined license plate. TABLE II shows the result. (1) In accurate stage the first method doesn't correct the inclined license plate. (2) The second method compute the inclined angle based on Hough transform to search parallel straight lines or rectangular. This method has large amount of calculation and when license plate frame is fuzzy the angular deviation is bigger; (3) The third method is rotation projection. Because it need to compute multiple rotating image projection, the method is slow, and the angular deviation is big; (4) The fourth method is PCA principal component analysis (PCA). In this method the angle is determined by solving the feature vector of the image principle element direction, the method has high accuracy, and is very fast; (5) The fifth method is Formula derivation. In this method the angle is deduced by the formula based on minimum variance principle. This method is fast and simple implementation. Results show formula derivation method is better to tilt correction in this paper.

TABLE II. ACCURATE DETECTION

Algorithm	Accurate Results	
	Precision	***Average time***
First method	93.69%	310ms
Second method	93.93%	740ms
Third method	94.67%	650ms
Fourth method	96.17%	460ms
Fifth method	96.6%	470ms

IV. CONCLUSIONS

In this paper, we presented a hybrid license plate detection scheme which is based on edge and color. Our database is complex and different in illumination conditions (day time, night time), background, camera angle etc. Considering all of these, the experiment results prove the proposed method is effective and it can also meet the requirement of real-time. It provides a lot of convenience for the next step.

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