Multi-features-based License Plate Detection in Nighttime Environment

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***Abstract*—We propose a novel method for license plate detection in nighttime videos with complicated background scenes. The proposed method use multi-features-based combination way in the residual edge image. Our work firstly is color space conversion from RGB to La*b* color space and get enhancement L component of license plate image, then extract out multi-features of license plate, thirdly, multi-features combination method is used to get license plate detection, finally, search the license plate localization and segment the characters from the original nighttime environment images by using nonlinear vector quantization method. The experimental results show that the proposed method has more robust to interference characters and more accurate when compared with other methods.**

***Index Terms*—license plate detection, multi-features, La*b*, nighttime environment, nonlinear vector quantization**

I. INTRODUCTION

In recent years, automatic license plate recognition (LPR) has been a practical technique in vehicle management. Numerous applications, such as security control of restricted areas [1], traffic law enforcement [2], automatic toll collection [3], criminal pursuit [4], and traffic law enforcement[5]etc. Due to different working environments, LPR techniques vary from application to application. LPR is generally divided into three steps: license plate detection(LPD), character segmentation, and character recognition. License plate detection roughly classifies LP and non-LP regions. Character segmentation separates the symbols/characters from each other in one LP. In this paper, we study towards automatic license plate detection in nighttime environment. Meanwhile, we also propose a novel method of character segmentation in license plate.

License plate detection technique has a long research history. Fig.1 is an example of license plates with high illumination and simple background. For these license plates case, the state-of-the-art methods of license plate detection can resolve these problems well. So we don't study these cases of license plate detection in this paper. License plate detection is still challenge problem because some methods restricted their working conditions [6], such as: fixed illumination, limited vehicle speeds, limited dynamic environment, or designated ranges of the distance between camera and vehicle. Feature-based way is commonly employed for license plate localization. These features regarding license plate format include shape, height-to-width ratio, color, texture of grayness. However, these traditional techniques can't satisfy different illumination and complicated background case. In this paper, we only discuss the nighttime environment (low illumination) images of license plate detection with complicated background scenes case. Fig.2 shows a good example of the nighttime environment images for our experimental data.

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Fig.1 an example of license plates with high illumination and simple background. Note that, we don't study these cases in this paper.

Fig.2 Sample original images in our data sets, the problems we address in this paper is that of license plate detection.

For the more accurate of license plate detection, the nighttime license plate should be enhancement as pre-processing in our method. Traditional image contrast enhancement technique can be broadly categorized into two groups: spatial-based domain and frequency-based domain. Spatial-based domain refers to the image plane itself, and approaches in this category are based on direct manipulation of pixels in an image [7]. Such as: power lower transform, tone mapping function etc. It is usually denoted by the expression [8]:

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$$g(x,y)=T[f(x,y)] \quad (1)$$

Where $f(x,y)$ is the input image, $g(x,y)$ is the processed image, and T is an operator on f, defined over some neighborhood of (x,y).

Frequency-based domain processing techniques are based on modifying the spatial frequency spectrum of the image as obtained by transform [8]. Such as: Fourier, wavelet, discrete cosine transforms.

Most existing color image enhancement techniques usually have some limitations: (1) color image enhancement applied in the RGB color space is inappropriate for the human visual system, (2) the uniform distribution constraint employed is not suitable for human visual perception, (3) the processing speed and complexity of the algorithm are crucial for applications in real time processing or mobile devices [7]. These traditional techniques can't satisfy nighttime environment and complicated background case. At present, some existing software have already provided noise removal and contrast enhancement functions, it is likely that most of them introduce artifacts and could not produce desirable results for a broad variety of illumination images[9]. In this paper, we propose the piecewise tone mapping method to enhance nighttime illumination images as pre-processing of license plate detection.

There has been a number of successful license plate detection works reported in [3,4]. Horizontal edges around a license plate are relatively strong and dominant, meanwhile density of vertical edges across a license plate are significant. Based on these two features, V. Abolghasemi et al.[3] proposed a method for detection of the license plates in 2D gray images. The location with significant density of vertical edges is estimated. To filter out false candidates in the obtained result, a match filter is designed to the instance of the license plate in the image. However, this method can't remove a very long curve and with high time complexity. Due license plate area contains rich edge and texture information, based on these features, Zhang et al.[4] proposed a real time and robust method of license plate location. Most of the background and noise edges are removed by an effective algorithm, and the plate regions are searched by using a rectangle window in the residual edge image and segment the plate out from the original car image. A drawback of this method is only resolve small and random noise, the long curves in background cannot be removed and cannot extract license plate accuracy well by this method. In this paper, we also use similar method with work [3,4] to overcome these drawbacks and get license plate detection well.

A wide variety of techniques to segment each character after license plate detection has been developed. Nomura et al. [5] performed an adaptive segmentation of characters, searching for natural segmentation points in the projection histogram and merging fragments that belong to the same character. For the aforementioned task, prior knowledge of the maximum quantity of segments for each set (letters or digits) was employed to decide whether the merging is necessary. Some researchers have employed local binarization methods [6,10] to segment characters. An image is divided into $m \times n$ blocks, and a threshold is chosen for each block. To efficiently deal with all possible combinations of candidate regions of characters local threshold techniques are used for each pixel. The threshold is computed by subtracting a constant c from the mean gray level in a $m \times n$ window centered in the pixel. The threshold is given by the Niblack binarization formula as follows,

$$T(i,j)=m(i,j)+k.\sigma(i,j) \quad (2)$$

where T is the threshold at pixel (i,j), $k=-0.2$ is a weight factor, and $\sigma(i,j)$, $m(i,j)$ are the standard deviation and the mean of the 15×15 local neighborhood of pixel (i,j), respectively.

All these works have some limitations as follows: (1) the high computing work and can't real-time implement. (2) For multi-characters of license plates with combination, these algorithms can't segment characters well. (3) These algorithms can't consider nighttime images with complicated background scenes. Nighttime images of license plate aren't very satisfying results. In this paper, we consider the nighttime images with complicated background scenes and propose a novel method for license plate localization, which is combine multi-features fusion method in the residual edge image.

Based on analysis above algorithms, in order to overcome these limitations of researcher's mentions, we propose a novel approach for license plate detection in nighttime environment with complicated background scenes. Meanwhile, we also propose a novel method of character segmentation of license plate. This paper introduces the following main results:

(1) Due to nighttime license plates images can't more accurate of license plate detection, we propose the piecewise tone mapping method to enhance nighttime video illumination as pre-processing of license plate detection.

(2) For license plate detection well, we propose a novel scanning way, which combine multi-features of license plate in the residual edge image.

(3) For character segmentation well, we use using nonlinear vector quantization method to segment characters of license plate.

The remainder of the paper is organized as follows. Section II describes related work. Section III gives the proposed methodology. Experimental results are presented in Section IV. Finally, the conclusion is given in Section V.

II. Related Work

License plate detection and character segmentation are an essential and important stage in license plate recognition, and it has received considerable attention. In the past decades, many methods have been proposed for LPR. However, since there are problems of license plate such as low illumination image, complicated background, and color similarity, the license plate detection is often difficult to be located accurately and efficiently. Many

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methods have been proposed in order to solve the problems. Such as: the features used, edge-based analysis, color-based algorithms, and textures-based algorithms, etc.

Features-based license plate detection commonly employed has been derived from the license plate format and the alphanumeric characters constituting license numbers. The features regarding license plate format include shape, symmetry, the width (or the height) of the region, size of the region, edge intensity, texture of grayness, spatial frequency, and variance of intensity values, and position of the region[1,11,12]. Jia et al. [13] proposed a region-based license plate detection method. Mean shift is used to filter and segment a color vehicle image in order to get candidate regions. However, if the characters of license plate are linked to other part, the method can't deal with these cases. V. Abolghasemi et al. [3] proposed a method for detection of the license plates in 2D gray images. The regions with high density vertical edges are used for license plates. A match filter is used in the edge density image in order to filter out clutter regions possessing similar feature. However, this method fails in nighttime environment. Combined with some prior geometrical properties of license plates, the methods can obtain good performance even when dealing with some deficient license plates[14]. However, these methods can only deal with images captured under very specific environment.

Color-based information of license plates also plays an important role in license plates detection, where the unique color or color combination between the license plates and vehicle bodies are considered as the key feature to locate the license plates. Zhu et al. [15] use color features for license plate detection. However, this method is sensitive to the license plate color and brightness and needs much processing time. Kim et al.[16] proposed an enhanced color texture-based method for license plate detection in images. The system analyzes the color and textural properties of license plates in images using a support vector machine and locates their bounding boxes by applying a continuous adaptive mean shift algorithm. The drawback of this method is that it still encountered problems when the image was extremely blurred or quite complex in color.

Texture-based analysis algorithm is another useful approach for license plate detection. Gabor filters have been one of the major tools for texture features analysis in multi-scales and multi-orientations to describe the texture properties of license plate. F. Kahraman et al.[17] proposed a method for license plate detection based on the Gabor Transform. The experiment results were encouraging (98% for LP detection) when applied to digital images acquired strictly in a fixed and specific angle. However, the proposed method is computationally expensive and slow for images with large analysis.

Edge-based analysis methods the aim is to detect boundaries of an image, including edge statistics, edge features, and edge density. Due to sufficient information from edges in the license plate, edge statistics yield promising results. Ming et al. [18] proposed using edge features and edge statistics information of the license plate image, which can be used to successfully detect license plate. However, using edge statistics information alone the rate of success is low especially in complex and nighttime environment images.

A wide variety of techniques to segment each character after license plate detection has been developed. Such as: projections and binary algorithms, feature vector extraction, contours-based method, etc.

Obtaining a binary image is to add up image columns or rows and obtain a vector (or projection), whose minimum values allow segment characters. CCA is also intensely involved in character segmentation, in conjunction with binary object measurements such as height, width, area, and orientation [19]. Usually, the CCA method labels the pixels into components based on 8-neighborhood connectivity. S. Nomura et al [20] proposed a novel adaptive approach for character segmentation and feature vector extraction from seriously degraded images. Histogram-based method automatically detects fragments and merges these fragments before segmenting the fragmented characters. Then a morphological thickening algorithm automatically locates reference lines for separating the overlapped characters. Contour tracking is also incorporated for character segmentation of license plate. A. Capar et al. [21] established a shape-driven active contour model, which utilizes a variable fast marching algorithm, and applied it to the plate character segmentation problem. M.R. Lyu et al.[22] proposed local threshold determination and slide window technique to improve the characters segmentation of license plate. Meanwhile, an improved method of the global optimization [23] is proposed. The goal is not to obtain good segmentation result for independent characters but to obtain a compromise of character spatial arrangement and single character recognition result.

Currently, most researchers prefer a hybrid license plate detection method, where multiple features are involved in order to make the method more robust. In order to address these drawbacks of the methods, our method is also a feature-based fusion method. We propose a novel method, which is involved edge density of license plate and rectangle shape in the residual edge image. In next section, we discuss the proposed framework for license plate detection and character segmentation in nighttime environment images with complicated background scenes.

III. Methodology

By observing license plate in images, two main features are noticed. First, density-based information of license plate region are relatively strong and dominant. Second, license plate is rectangularity region in complicated background with low illumination and noise. These two important features and low complexity for edge-based analysis motivate us to use multi-features-based method for the license plate detection.

The detailed procedures of the proposed method can be described as in Fig.3. The proposed method is composed

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of the following steps: (1) conversion of RGB to La*b* and extract L component, (2) L component enhancement of license plate, (3) density-based information analysis, (4) extract out the rectangularity region of the nighttime license plate from L component, (5) license plate detection, and (6) characters segmentation from the nighttime environment images. These steps are described in details in the following.

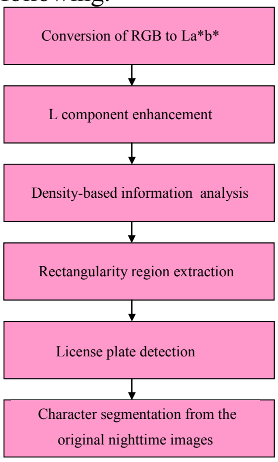

Fig.3 A block diagram of the proposed license plate detection and character segmentation method.

A. Conversion of RGB to La*b*

A proper color space for color image enhancement should decouple the achromatic and chromatic information and should be close to the color perceiving properties of the human visual system. In order to satisfy this goal, we use the La*b* color space. RGB color space contains both intensity and color information which can be separated into intensity and color information using La*b* color model. The La*b* color components are given by the following [8]. First, conversion from RGB to XYZ is given as follows.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412 & 0.358 & 0.180 \\ 0.213 & 0.715 & 0.072 \\ 0.019 & 0.119 & 0.950 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (3)$$

Then from XYZ to La*b* is given as follows.

$$I = 116.h(\frac{Y}{Y_w}) - 16 \quad (4)$$

$$a^* = 500[h(\frac{X}{X_w}) - h(\frac{Y}{Y_w})] \quad (5)$$

$$b^* = 200[h(\frac{Y}{Y_w}) - h(\frac{Z}{Z_w})] \quad (6)$$

where

$$h(q) = \begin{cases} \sqrt[3]{q} \\ 7.787q + 16/116 \end{cases} \begin{cases} q > 0.008856 \\ q \le 0.008856 \end{cases}$$

X_w, Y_w, and Z_w are the reference white tri-stimulus values. Some examples of the RGB components and their converted La*b* components are shown in Fig.4.

Fig.4 Conversion RGB to La*b* color space (a) original image, (b) L component, (c) colored a* component, (d) colored b* component.

B. Piecewise Fusion for License Plate Enhancement

Although most image enhancement methods can effectively improve the perception of information for human viewers, they still have some limitations, such as the loss of local contrast and the loss of details [9]. There is no single method that can overcome all of the limitations. After color space conversion from RGB to La*b* color space, in order to create global tone mapping curves, we propose piecewise fusion strategy to enhance L component.

Inputted L component can be divided into two interest regions $f_A(L(x,y))$ (low illumination part,) and $f_B(L(x,y))$ (high illumination part). The expression is shown as follow.

$$f(L(x,y)) = \begin{cases} f_A(L(x,y)) & if \quad L \in [0, T] \\ f_B(L(x,y)) & if \quad L \in [T, 255] \end{cases} \quad (7)$$

Here, L is illumination value of the video frames. T is a threshold, which is used the conjunctive the two parts. In this paper, we use two piecewise tone mapping method to enhance the input video frames. Its detailed description is presented as following:

$$\begin{cases} f_A(0) = 0 \\ f_B(255) = 255 \\ f(L(x,y)) = \alpha * f_A(L(x,y)) + \beta * f_B(L(x,y)) \\ \alpha + \beta \le 1 \end{cases} \quad (8)$$

where $\alpha + \beta$ less than or equal 1, α and β are used to determine the level of the similarity between $f_A(L(x,y))$ and $f_B(L(x,y))$. In general, α is set more than 0.5, β is set less than 0.5. An experimental result of enhanced video frame with license plate is shown in Fig.5.

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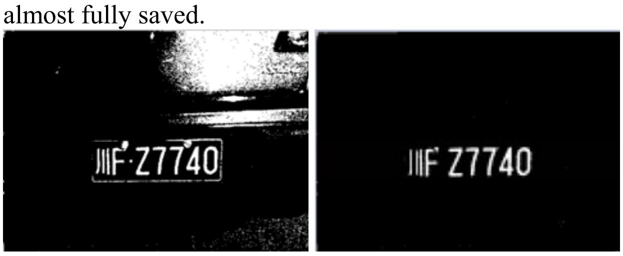
(a) (b)

Fig.5 (a) L component of license plate with complicated background scene. (b) enhanced L component of license plate nighttime environment scene using our method.

C. Multi-features-based Method for License Plate Detection

By observing inputted nighttime videos frames, the important shaper feature of license plates is that vehicle images can be viewed approximately as rectangle shape with a certain aspect ratio. The rectangle region $R_{m\times n}$ is defined as the total number of pixels in the region of license plates. Another important features is that edge density across license plates are significant, while background edges are usually either long curves or very short. It is observed that most of the vehicles usually have more horizontal edges than vertical edges.

In this paper, we firstly use Sobel to obtain the edge density of the input nighttime videos frames. Then we use morphological opening, closing, and connected component to perform on the binary masks to get rid of small and random noises, and to fill the holes [7]. Due to complicated background, some long curves and big holes still have exiting on low illumination image. We use the similar method with work [8,24] to remove long curves and random noise. In our method, we accumulate the edge lengths through observing the "concerned neighborhood pixels" of the current pixels $P(i, j)$. Fig.6 shows a experimental result, From Fig.6(b), most of the background curve and random noise have been eliminated, but the license plate localization edges are almost fully saved.



(a) (b)

Fig.6 (a) the original binary image after vertical edge extraction. (b) the result of long curve and random noise removing from the original binary image.

In order to detect license plate region, rectangle and edge density two features is used to remove non-license plate region. The edge density is measured in a region $R_{m\times n}$ by averaging the intensities of all edge pixels within the region as

$$D_R = \frac{1}{M_R} \sum_{m,n\in R} Eege\ (m,n) \tag{9}$$

where $Eege\ (m,n)$ represents the edge magnitude at location (m,n), and M_R is the number of pixels in region $R_{m\times n}$.

After get edge density of region $R_{m\times n}$, the most straightforward method is to set a threshold or applying a Gaussian kernel to get license plate detection. Such as work in [4, 13]. According to license plate rectangle shape, we can shift a rectangle window (SRC) whose size is just bigger than that of the license plate from left-to-right and top-to-bottom in the edge image to count the total number of the edge density D_R. It is called SRC method in this paper. If edge density of rectangle window $D_R > Th$, rectangle window is a license plate detection region. Here Th is a threshold, which is counted by using ratio way of license plate height and width. In our work, it is set an experience vale. If using $D_R > Th$ detection has more one regions, it is described as following.

$$D_R = \{D_{R1}, D_{R2}, D_{R3} \ldots D_{Rn}\} \tag{10}$$

In our work, the bubble sort algorithm is used to search license plate region D_R. The detail step of the proposed method is shown as follows:

Algorithm 1 license plate detection method

Input: input nighttime video frames with complicated background.

Procedure:

Step1: conversion of RGB to La*b* color space and extract L component.

Step2: L component is enhanced using piecewise fusion strategy, the detailed description see Eq.(8).

Step3: using Sobel and morphological opening, closing, and connected component to obtain the edge density of the input nighttime videos frames.

Step4: according to license plate rectangle shape and edge density, for each row i from left to right to shift a rectangle window, for each column j from top to bottom to shift a rectangle window.

Step5: the output results of license plate detection.

An experimental result of proposed license plate detection is shown in Fig.7.

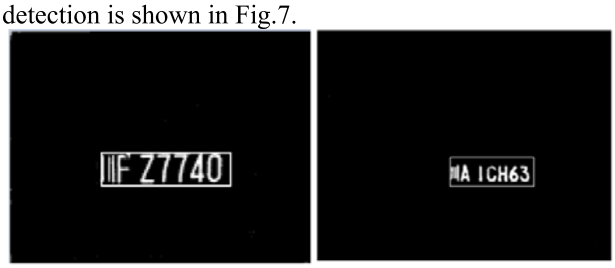


Fig.7 The results of license plate detection using the proposed method.

D. Character Segmentation of License Plate

After the enhancement processing and license plate detection background, license plate is detected in nighttime environment with complicated background.

For character segmentation, many works have been developed for character segmentation of license plate. Nomura et al. [25] proposed a morphological thinning

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algorithm and the segmentation cost calculation automatically determine the baseline for segmenting the connected characters. Xia et al.[26] used vertical image projection, which boundaries from the noise-free license plate image are removed before applying vertical projection histogram in order to threshold the histogram bin value to zero.

In this paper, we use similar work[2,25,26,27] for character segmentation of license plate. We propose a novel automatically character segmentation method, which use the nonlinear vector quantization method. Quantization vector(q_n) is assumed to be equal to the class mean:

$$q_n = \frac{m_n}{K_n} \tag{11}$$

$$m_n = \sum_{s \in C_n} I_s \tag{12}$$

$$K_n = | C_n | \tag{13}$$

where C_n is the set of pixels assigned to the vector q_n. I_s is binary image. Initially all pixels belong to the same class whose vector is the average of the image. Then the class is divided into two sub classes denoted by C_{2n} and C_{2n+1}. The vectors associated with these sub classes are chosen based on the second order statistics within the class R_n. Class covariance matrix is given as:

$$\overline{R_n} = R_n - \frac{1}{K_n} m_n m_n^T \tag{14}$$

In this paper, the quantization error E is minimized as follows.

$$E = \sum_{n \in Q} \sum_{s \in C_n} \| I_s - q_n \|^2 \tag{15}$$

Once the unit vectors E_n are obtained, the pixels belonging to the class C_n are assigned to C_{2n} or C_{2n+1} as follows.

$$C_{2n} = \{ s \in C_n : E_n^T I_s \le E_n^T q_n \} \tag{16}$$

$$C_{2n+1} = \{ s \in C_n : E_n^T I_s > E_n^T q_n \} \tag{17}$$

Splitting classes stops either when maximum vector number is reached or when the class variance is less than a predefined threshold. In this paper, we use two levels image, the resultant image is binary. An experimental result of character segmentation in license plate is shown in Fig.8. The rest task is characters recognition, in our work we don't discuss.

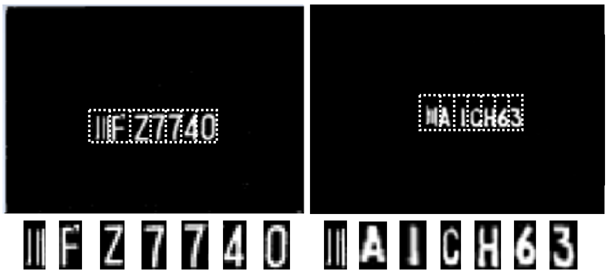

Fig.8 the results of character segmentation using our method

IV EXPERIMENTAL RESULTS

In this section, in order to demonstrate the performance of the proposed method, we show experimental results for our proposed multi-features-based nighttime license plate detection. As far as researchers know, due to different area/country, nighttime license plates database isn't standard for researching. In our experiments, we use different images and videos by digital camera or fixed surveillance camera in intersection, highway, campus, community. In order to show our nighttime license plate detection method well, Fig.9 shows a complete experimental processing and the results of license plate detection. From this figure, it show robustness of the multi-features-based nighttime license plate detection and overcomes the drawback of the traditional methods.

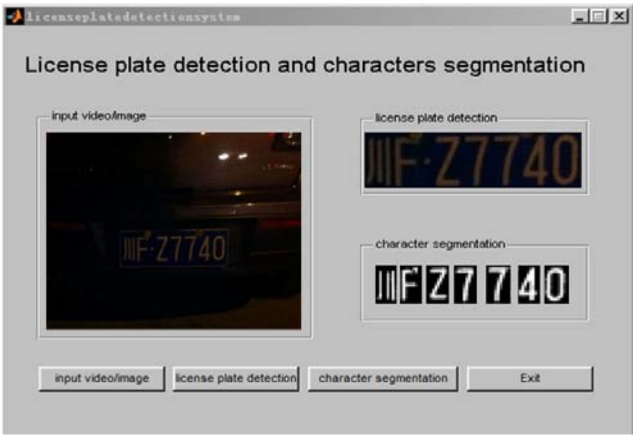

Fig.9 the nighttime license plate detection and segmentation system developed based on our proposed method.

In order to estimate the method efficient, various data sets of license plate are used in the proposed method. Our license plate data set has 15videos, total 4506 frames with license plate. These frames have been taken from natural scenes mainly with complicated background and under different nighttime illumination. Some input frames and the result of license plate has been shown in Fig.10. These results indicate that the proposed method is quite able to discriminate and to produce a rough estimate of the plate.

Fig.10 the first column is original nighttime license plate image with complicated background scene, the second column is experimental results using Sobel operation, the third column is experimental results of license plates detection, the fourth column is experimental results of character segmentation of license plates.

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To make a trade-off between accuracy and speed by altering the introduced threshold, some state-of-the-art well-reported methods and the proposed method is comparison. The experimental results in the literature are given in Table 1.

TABLE 1

A COMPARISON OF SOME STATE-OF-THE-ART WELL-REPORTED METHODS AND OUR PROPOSED METHOD.

Ref.	LPD rate	Time(sec)	LDP methods
[3]	89.12	36.3	Edge-based feature analysis
[4]	86.18	35.7	Texture features analysis
[13]	75.26	34.5	Region-based shift in license plate
[17]	90.01	35.2	Gabor transform and vector quantization
[24]	87.41	32.5	Vertical projection
Our method	91.75	30.2	Rectangle shape of license plate and density-based information fusion

All the experiments were performed on PC running Windows XP. The PC is 3.0GHz Intel Xeon i5 3470 processor, Intel GMA HD 4000 graphics card, and 8GB of RAM. The average processing times for the four stages of the proposed method are listed in Table 2. Form this table, we find that a lot of the time is consumed on the second stage "piecewise fusion for license plate enhancement". The total time of processing average 312 fames with size 800×512 is 30.2 ms, and it meets the requirement of real time processing.

TABLE 2

THE PROCESSING TIMES FOR THE FOUR STAGES IN THE PROPOSED METHOD (UNIT: MS)

color space conversion	piecewise fusion for license plate enhancement	license plate detection	character segmentation	Total time
6.4	9.8	5.8	8.2	30.2

V CONCLUSIONS

This paper strives toward a novel methodology that aids automatic license plate detection, characters segmentation of processing. Our methodology is multi-features-based, which combine rectangle shape of license plate and density-based information in the residual edge image. Experimental results show that the proposed method achieve a good license plate detection rate for complicated background scene images. It also shows more accurate license plate characters segmentation results than the state-of-the-art methods.

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