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Method of License Plate Location Based on Edge Detection and Color Information

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***Abstract*—A new method of license plate location is designed in the paper and it is divided into two steps, which are rough location step based on gray image processing and precise location step based on color image processing. Firstly, the color car image is converted to the gray one from which horizontal and vertical edge images are extracted using Haar wavelet and Gabor filter. The rough location is achieved based on the specific projection features of these edge images. Then the color plate image roughly located by the first step is converted to HSI space. The binary image is obtained through the threshold segmentation method according to the color information of license plate. The plate's precise position parameters are determined through making projection analysis of the binary image. The simulation result shows that the location method in this paper is efficient and effective.**

Keywords- plate location, edge detection, Haar wavelet, Gabor filter, projection analysis, binarization

I. INTRODUCTION

With the rapid development of digital image processing and computer technology, intelligent traffic management system must be trend of transportation management system during the 21st century; automatic license plate recognition system is a quite important section of intelligent traffic management system, which involves the license plate location, character segmentation and character recognition. Among these three parts, license plate location, as the basis of other two parts, is an important one of the whole system. The current license plate location methods are usually based on the mathematical morphology [4], wavelet analysis [4, 7, 8], projection analysis [5, 6, 9, 10] and the color image processing [5]. The method based on the color image processing can locate the license plate more accurately, but the location error will increase if the color of license plate is very similar to background. Some other location methods have small computation and low complexity which can meet the requirement of real-time, but there still exist some problems such as lower locating accuracy and poor robustness.

The features of the target image should be analyzed carefully according to theory of image segmentation [1-3]. In China, the shape of license plate is 14cm*44cm rectangle, and in other words its aspect ratio, length and width each has a particular specification. There are mainly two kinds of license plate. One kind of plate has white characters and blue background; the other one has black characters and yellow background. There are rich edge details in the license plate region; the number of gray level transition between plate character areas and plate backgrounds is also specific.

After conducting a research on the current location methods and analyzing carefully the features of license plate, a new plate location method based on edge detection and color information is presented in this paper. It is composed of two steps, which are the rough location step and the precise location step. The rough location step is based on gray image processing and the precise location step is based on color image processing. This is just the difference from other location methods. Figure 1 shows the plate location diagram.

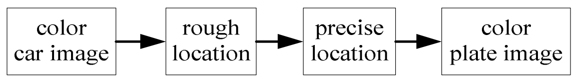

Figure 1. Plate location diagram

II. ROUGH LOCATION

Because of the large data volumes, processing color image directly will increase the computation, running time and hardware performance requirements. This is why the rough location method presented in the paper is based on gray image processing. For the rough location method, the color car image is pre-processed through the way of grayscale conversion and de-noising; vertical edge image is extracted from the preprocessed image using wavelet transform; the up and down position parameters of the plate are determined by analyzing the projection features of vertical edge image. The horizontal edge image is extracted from the above processed image using Gabor filter, and the right and left position parameters of plate are obtained through making projection analysis of the horizontal edge image. The rough location process is shown in Figure 2.

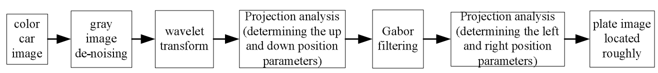

Figure 2. the rough location process of license plate

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A. Grayscale conversion and de-noising.

The RGB color model image can be converted to the gray one through the following equation:

$$\text{gray} = 0.11 * \text{r} + 0.59 * \text{g} + 0.23 * \text{b} \qquad (1)$$

where, gray denotes the gray level of a pixel in the gray image; r, g and b represent respectively value of color component of the pixel in the color image.

In order to facilitate the subsequent processing, Gaussian low-pass filter is applied to remove noises in the roughly located plate image.

B. Up-down location based on wavelet transforms

1) Wavelet analysis: Wavelet transform is a partial Fourier transform with the characteristics of local transformation between the space (time) and frequency domain. The signal is refined based on multi-resolution analysis through stretches and translation, with the ultimate result of time segmenting at high frequencies and frequency segmenting at low frequencies. Therefore the detail characteristics of signal can be obtained effectively. That is why this paper uses wavelet analysis to extract vertical edges from the gray car image. In order to improve processing speed, Haar wavelet is chosen.

Haar function is a wavelet function with the unit height and width, as shown in Equation (2). It is extended to 2-D space according to the equation $\varphi(x, y) = \varphi(x) * \varphi(y)$. The 2-D form $\varphi(x, y)$ obtained is shown in Equation (3).

$$\varphi(x) = \begin{cases} 1 & 0 \le x < 1 \\ 0 & \text{other} \end{cases} \qquad (2)$$

$$\varphi_{a,b}(x, y) = \frac{1}{a}\varphi\left(\frac{x-b}{a}, \frac{y-b}{a}\right)$$
$$a = 2^k; b, k \in Z \qquad (3)$$

$\varphi(x, y)$ is stretched and translated in the way of two-telescope, resulting in a series of wavelet functions according to Equation (3). Then the vertical detail sub-image $f(x, y)$ is extracted from the preprocessed car image $I(x, y)$ through the two-dimensional wavelet decomposition. Figure 3(a) shows the preprocessed car image $I(x, y)$ with a size of $2M * 2N$; Figure 3(b) shows its vertical edge image $f(x, y)$ with a size of $M * N$.

(a) the preprocessed image

(b) vertical edge image of Figure 3(a)

(c) the energy image of Figure 3(b)

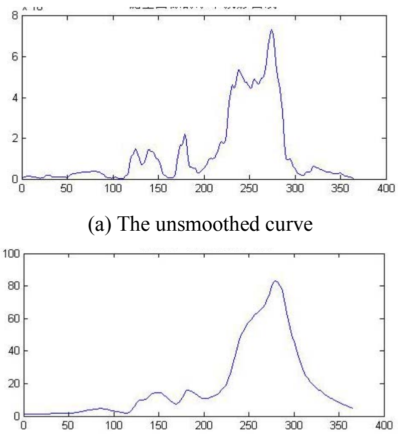
Figure 3.

2) Horizontal projection analysis: In order to obtain better location effect, the energy of the vertical edge image is calculated before making projection analysis. Energy calculation method is denoted by Equation (4), where $f(x, y)$ is the vertical edge image, $e(x, y)$ is its energy image. The neighborhood about pixel (x, y) is denoted as a square region with a size of $n*n$, where n takes value of 3,5 and 7 usually. Experimental analysis shows that the location effect is poor when n equals 3 and the computation is large when n equals 7, so n takes the value of 5 in this paper. Figure 3(c) denotes the energy image of vertical edge image shown in figure 3(b).

$$e(x, y) = \sum_{i=-\frac{n-1}{2}}^{\frac{n-1}{2}} \sum_{j=-\frac{n-1}{2}}^{\frac{n-1}{2}} f^2(x+i, y+j)$$
$$\text{x} = \frac{n+1}{2}, \frac{n+3}{2}, \ldots, \text{M} - \frac{n-1}{2},$$
$$\text{y} = \frac{n+1}{2}, \frac{n+3}{2}, \ldots, \text{N} - \frac{n-1}{2} \qquad (4)$$

$\text{e}'(y)$ is the projection curve calculated through horizontal projection of $e(x, y)$. In order to facilitate the following process, an improved weighted average algorithm is used to smooth the curve .The smoothing principle is given by Equation (5). In this equation, $\text{e}(y)$ is the smoothed curve with $e(0) = \text{e}'(1)$, λ denotes the weighted coefficient taking value in (0, 1). Experiment results prove that the smoothing effect is the best when $\lambda = 0.2$. Figure 4 shows the smoothed and unsmoothed curves.

$$e(y) = \lambda * \text{e}'(\text{y}) + (1-\lambda) * e(y-1)$$
$$e(0) = \text{e}'(1) \qquad (5)$$



(a) The unsmoothed curve

(b) The smoothed curve

Figure 4.

Then, $e(y)$ is normalized to taking value in $[0, 1]$. According to the normalized curve, the up and down position parameters of plate are determined through making horizontal projection analysis. The roughly located plate image is obtained based on the up and down position parameters.

C. Left-right location based on Gabor filtering

In order to determine the left and right position parameters of license plate, Gabor filter is used to detect the horizontal edges of image as it has better directionality.

Gabor function is a Gaussian function modulated by a complex sine function. Gabor filter has good band-pass performance and directionality, so it can detect local texture features effectively. The 2-D Gabor function is denoted as

$$h(x,y) = g(x',y')\exp(2\pi jFx')$$
$$g(x',y') = \frac{1}{2\pi\sigma_x\sigma_y}\exp\left\{-\frac{1}{2}\left[\frac{(x')^2}{\sigma_x^2}+\frac{(y')^2}{\sigma_y^2}\right]\right\} \quad (6)$$
$$x' = x\cos\theta + y\sin\theta,$$
$$y' = -x\sin\theta + y\cos\theta$$

where, F denotes the filter's center frequency, θ indicates the modulation direction of Gaussian functions and determines the direction of texture detected by Gabor filter; σ_x and σ_y are the standard deviations along axis direction. Equation (7) denotes the frequency form of Gabor filter.

$$H(u,v) = \exp\left\{-\frac{1}{2}\left[\frac{(u'-F)^2}{\sigma_u^2}+\frac{(v')^2}{\sigma_v^2}\right]\right\}$$
$$u' = u\cos\theta + v\sin\theta \quad (7)$$
$$v' = -u\sin\theta + v\cos\theta$$

where, (u,v) is the spatial frequency variable, σ_u and σ_v are the frequency standard deviations determining the size of Gabor filter's effective region in the frequency domain.

Gabor filter is designed according to Equation (7). The filter parameters are determined based on the following consideration. In order to extract the horizontal edges, the directional angle θ should be set as $0°$. The filter's center frequency takes the value of $60°$, that is determined by experiment. σ_x and σ_y are calculated according to the direction-bandwidth equation shown in Equation (8), where $\sigma = \sigma_x = \sigma_y$, $\sigma_u\sigma_x = 1/2\pi$, the experience value of Ω is $\pi/4$ and $\alpha = \sqrt{\ln 2/2}$. According to these parameters, the value of σ is calculated as 21.4.

$$\Omega = 2\tan^{-1}\frac{\alpha}{\pi F\sigma} \quad (8)$$

Then, through filtering the horizontal edges are extracted from image obtained in section 1.2. The left and right position parameters of plate are determined through making projection analysis. The color plate image can be obtained based on four position parameters of plate in the original color car image. Figure 5 is the color plate image located, which shows that most of non-plate region has been removed after rough location.

Figure 5. the license plate located roughly

III. PRECISE LOCATION

The precise location process of plate in this paper is based on the color plate image obtained through rough location. The detailed process is shown in Figure 6.

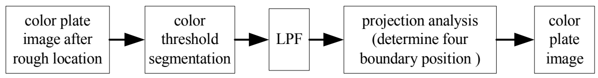


Figure 6. diagram of the precise location of plate

HSI color model is based on the human visual system. In this model, color brightness is described by the components of hue, saturation and brightness. Therefore, this model is more similar to human vision, easier to be accepted and more intuitive. In addition, the three color components (H, S and I) are mutually independent, so they can be processed separately. In the precise location of plate, the color plate image located by the rough location of plate is converted from RGB model to HSI one, and then the HSI model image is converted to the binary image based on the method of threshold segmentation.

There are four kinds of color appearing in the plate region to be processed in this paper. They are respectively blue and yellow which are plate background colors, white and black which are character colors. The value range of four colors in the HSI color space is shown in Table 1. According to the data in Table 1, segmentation threshold of each color component is determined. According to the plate background color, the color plate image obtained through rough location is processed based on Equation (9), where $h(x,y)$, $s(x,y)$ and $v(x,y)$ denote three color components in the HSI color space of the plate image, $p(x,y)$ is the binary image shown in Figure 7.

$$p(x, y) = \begin{cases} 1 & \begin{array}{l} 0.51 < h(x, y) < 0.68 \text{ and } s(x, y) > 0.33 \\ \text{and } v(x, y) > 0.3 \text{ or } 0.06 < h(x, y) < 0.16 \\ \text{and } s(x, y) > 0.33 \text{ and } v(x, y) > 0.3 \end{array} \\ 0 & \text{else} \end{cases} \tag{9}$$

TABLE I. the value range of four colors in the HSI space

	Blue	Yellow	White	Black
H	[0.53, 0.68]	[0.07, 0.13]	—	—
S	[0.35, 1]	[0.35, 1]	[0, 0.1]	—
I	[0.3, 1]	[0.3, 1]	[0.91, 1]	[0, 0.35]

The pixels outside license plate region can also be mistaken as the plate background pixels, so there will be discrete noises in the binary image obtained. Because the plate background region and the plate character region are respectively connected before and after the threshold segmentation, the noises mainly appear in the non-plate regions. Gaussian low-pass filter is used to remove these noises in order to locate the plate precisely.

Last, the precise position parameters of license plate are obtained by the method of making both horizontal and vertical projection analysis. The located color plate image is segmented based on the precise position parameters of plate in the original color car image. Figure 8 shows the located color plate image.

Figure 7. binary image

Figure 8. located color plate image

IV. CONCLUSIONS

In this paper a new plate location method is given after conducting a research on advantages and disadvantages of the current license plate location methods. This method includes two steps, which are the rough location based on gray image processing and the precise location based on color image processing. The method makes full use of the plate's edges and color information. Simulation is carried out on the platform of MATLAB7.6. 24 color car images are processed, which are all collected from various scenes. These cars have different types and colors. As a result, 21 license plates can be located accurately, and the locating accuracy is 92%.The simulation results show that the location method can locate the license plate more accurately. It has good robustness and certain application value. However, the locating accuracy is low if there are serious stains or obvious tilts in the plate region. The plate location method presented in this paper still needs to be improved.

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