License Plate Extraction Based on Vertical Edge Detection and Mathematical Morphology

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***Abstract*—License plate recognition plays an important role in Intelligent Transport System; however, plate region extraction is the key step before the final recognition. In this paper, an effective license plate extraction algorithm based on vertical edge detection and mathematical morphology is proposed, which can exactly extract the plate from complex background. The proposed algorithm mainly consists of two modules: license plate region's rough detection and license plate accurate detection. The former aims to find out Region of Interest (ROI) through a sequence of steps including vertical edge detection, edge detection and mathematical morphology, while the latter analyzes the ROI by taking full advantage of outer shape feature and inner texture feature of license plate. Experiments have been conducted for this algorithm.400 images taken from various scenes were employed, including diverse angles, different lightening conditions, etc. The proposed algorithm can detect the region of license plate quickly with 98.1 percent accuracy.**

Keywords-license plate location; edge enhancement; sobel operators; SE

I. INTRODUCTION

With the development of Intelligent Transport System (ITS), license plate recognition (LPR) plays an important role in numerous applications in reality, such as parking lots [1], automatic toll collection [2], law enforcement [3][4], security and speed limit enforcement [5]. But due to more and more cars in China, it is impossible for direct human intervention in these situations. So designing an effective LPR connecting with database is necessary, which will be much more convenient for managing cars. A typical LPR system consists of three modules: License Plate Extraction, Segmentation and Recognition of individual characters. Among these three modules, license plate extraction is the key one, which influences the accuracy of the system significantly. And this paper mainly focuses on license plate extraction.

Nowadays, a number of methods for license plate extraction are widely used. Edge extraction [6], Hough transform [7], histogram analysis [8], sliding concentric windows [9] are some examples of these methods. But most methods either have in some way restricted their working conditions such as stationary backgrounds, fixed illumination, no slanting angles and high resolution etc., or are time-consuming. In response to the features above, we propose a novel approach for license plate extraction in complex background.

The method proposed in this paper is mainly based on vertical edge detection and mathematical morphology (MM).It consists of four steps: vertical edge detection, edge enhancement, MM and Region of Interest (ROI) analysis. The specific processes can be described as follows: First, we transform the color JPEG image of 24bpp into gray-scale BMP image of 8bpp. Next, we use the Sotropic Sobel vertical edge operators to detect the vertical edge of image and enhance it through linear gray-scale transformation. And then we adopt a series of Closing and Opening operations of MM to get ROI. At last, outer shape feature and inner texture feature of license plate are taken full advantage of in ROI analysis. In the meanwhile, vertical and horizontal projection combining with ratio of width and height are utilized to screen out the license plate accurately. The rest of this paper is organized as follows: section II introduces the algorithm in detail, section III shows the details of the proposed algorithm. The experimental results and conclusions are discussed in section IV and V respectively.

II. MAIN ALGORITHM IN THIS PAPER

A. Edge Detection

The edge detection operators that we usually use are Robert operator, Sobel operator, Prewitt operator and Krisch operator. But through experiments we have discovered that Sotropic Sobel operator has a maximum response to edge. There are two masks for Sotropic Sobel, one is horizontal and the other is a vertical one. The mask is convolved with each pixel of the image. Figure 1 shows these two masks.

$$\begin{pmatrix} -1 & 0 & 1 \\ -\sqrt{2} & 0 & \sqrt{2} \\ -1 & 0 & 1 \end{pmatrix} \qquad \begin{pmatrix} -1 & -\sqrt{2} & -1 \\ 0 & 0 & 0 \\ 1 & \sqrt{2} & 1 \end{pmatrix}$$

Figure 1. Vertical mask and Horizontal mask

B. Linear Gray-scale Transformation

The details of an image will be obscure when the image is under-exposed or over-exposed or when the nonlinear dynamical range of imaging device or recording device is too narrow. And in these circumstances, if we extend the gray-scale of image linearly, we can usually improve the image's visual effect.

Supposing the gray-scale range of the source image $f(x,y)$ is $[a,b]$, and the expected dynamical range of transformed image $g(x,y)$ is $[c,d]$, then we can use the equation (1) to achieve our purpose.

$$g(x,y)=\frac{(d-c)[f(x,y)-a]}{b-a}+c \tag{1}$$

C. *Mathematical Morphology(MM)*

Built on the basis of set theory, MM [8, 9] is a nonlinear theory for image processing and analysis. Recently, the MM theory has been widely used in the fields of image processing and computer vision. MM makes use of Structure Element (SE) for measuring the morphology of image to solve and understand problems accurately. An SE can be of different geometrical shape and size. But the shape of SE widely used now is the form of line (usually horizontal or vertical), and the size is usually computed according to the specific conditions. Erosion and dilation are the two basic MM operations, which are carried out by convolving the SE with the image. Erosion is often used to remove irrelevant details from binary image, but on the contrary, dilation is used to fill in the gaps or holes. Now let B denote an SE, A stands for the input source image, X represents the result of erosion or dilation, then the operation of erosion and dilation can be defined as equation (2) and equation (3), and illustrated in Figure2 and Figure3:

$$X = A \Theta B = \{X : B - X \subset A\} \tag{2}$$

$$X = A \oplus B = \{X : -B - X \cap A \neq \varnothing\} \tag{3}$$

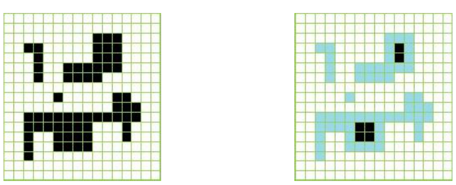

Figure 2. Erosion(SE is 3×3 square)

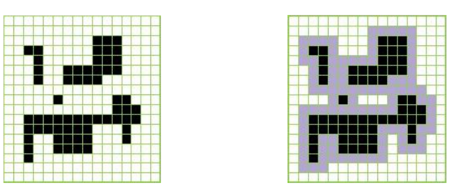

Figure 3. Dilation(SE is 3×3 square)

There're another two operations of MM named Opening and Closing, which are derived from erosion and dilation. Opening is obtained by eroding the image with an SE firstly, and then dilating the result with the same SE. It can erase white holes on dark objects or can remove small white objects in a dark background. An object will be erased if the SE does not fit within it. And it is defined as equation （4） and illustrated in Figure4：

$$A \circ B = (A \Theta B) \oplus B \tag{4}$$

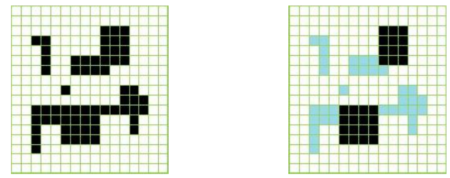

Figure 4. Opening(SE is 3×3 square)

Closing is obtained by dilating the image with an SE firstly and then eroding the result with the same SE. It can remove black holes on white objects. The hole will be removed if the SE does not fit within it. And it is defined as equation（5）and illustrated in Figure5：

$$A \bullet B = (A \oplus B) \Theta B \tag{5}$$

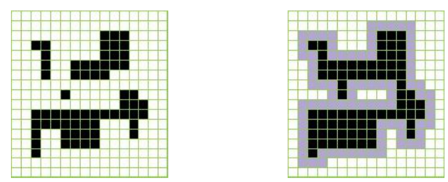

Figure 5. Closing(SE is 3×3 square)

D. *Projection Analysis*

Vertical and Horizontal projections can compute the number of pixels of per line. They are similar to histogram but they can give us the important message about spatial distribution of ROI. Combining the projection with thresholding, we can effectively segment the connected components from the image with noises.

III. Proposed Algorithm

Considering that license plate of China evolves four colors which are extremely sensitive to illumination, we firstly convert the color JPEG image to RGB color BMP image, and then to BMP image of gray-scale with method of a weighted sum. The transform equation is defined as follows [10]:

$$V_{gray} = 0.299R + 0.587G + 0.114B \tag{6}$$

Here, the character R, G, B respectively stands for Red, Green, Blue component of color.

The position of license plate can be obtained through a sequence of steps which include vertical edge detection, edge enhancement, MM and ROI analysis. Based on prior knowledge that characters in license plate have more vertical edges and car regions without license plate have more horizontal edge, we first choose Sotropic Sobel vertical edge detect operator to improve Signal-to-Noise Ratio(SNR).Then we improve the visibility of image by using linear gray-scale conversion and edge enhancement. And next, MM operations are used to fill in the gaps among characters. Now, a rectangular region is obtained. The flowchart of the whole algorithm is shown in Figure 6.

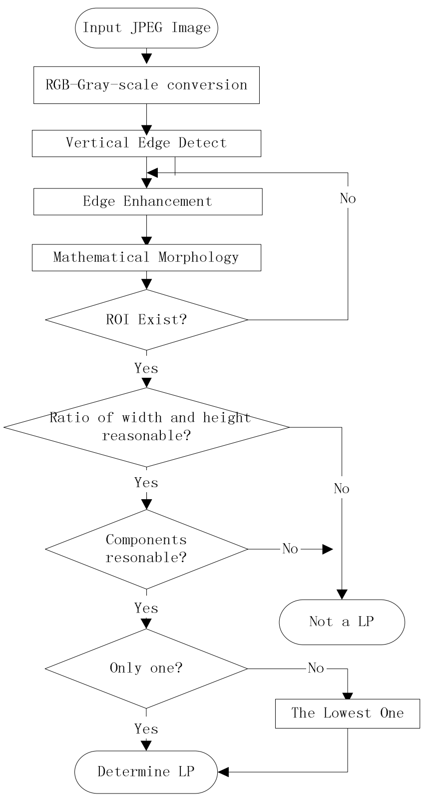

Figure 6. The flowchart of the algorithm

A. Vertical Edge Detection

An input car image is shown in Figure 7. The corresponding gray-scale image is shown in Figure 8. An output image is obtained shown in Figure 9 by applying Sotropic Sobel vertical edge detector to the input image. Due to the presence of several characters in license plate region, more vertical edges are detected in this region. This result is very useful for the later operations including edge enhancement and MM operations.

Figure 7.Original car image

Figure 8.Gray-scale image

B. Edge Enhancement

To the under-exposed input car image, the edge information in Figure 9 is not rich enough. So extending the range of gray-scale is necessary. We extend the range of original gray-scale of [60,120] to expected gray-scale of [0,255]. This makes more gray-scale pixels engage in the MM operations. Considering that the license plate is generally located at the bottom and in order to reduce computing time, we begin the transformation from one third height of the whole image. Then we enhance the image to obtain the image shown in Figure 10.

Figure 9.Vertical edge detection

Figure 10.Edge enhancement

C. MM Operations

The typical license plate in China is composed of 7 characters. Among these characters, the gap between the second one and the third one is the largest. To eliminate the gap, we choose the largest gap as the important reference value of designing horizontal SE. Supposing the largest gap is n, we design the size of horizontal SE (L) by the sentence: L = (n%2 ? n : n+1); We set global threshold of Figure 10 to 120. The output obtained after this Closing operation with SE is shown in Figure 11.

In practice, we usually cannot completely fill in the gaps of license plate by making Closing operation only once. And if the gaps can't be timely filled in, they will become larger and larger under the influence of the followed Opening operation. Thus, it is necessary to make another Closing operation shown in Figure 12. We get the white license plate without holes only by using a small vertical SE. Due to the last Closing operation, the residual black holes in license plate are much smaller.

The next target is to consider eliminating the regions that do not contain the license plate. We fulfill it by performing a sequence of two Opening operations. The first Opening operation to the image (Figure 12) is completed by using a SE whose size can't exceed the maximum of license plate width. Now, the regions whose widths are less than SE are eliminated. The output image obtained after the first Opening operation is shown in Figure 13.

The second Opening operation to the image (Figure 13) is carried out by using a SE whose size can't exceed the maximum of license plate height. Then, the noise blocks whose heights are less than SE are eliminated. The result is shown in Figure 14. As a result, ROI are obtained. If no ROI is fixed, then it will return to the step B to adjust the range of gray-scale. The output image is shown in Figure 15.

Figure 11.Closing with horizontal SE

Figure 12.Closing with vertical SE

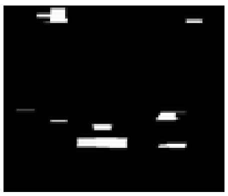

Figure13.Opening with horizontal SE

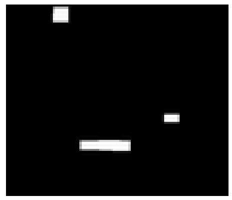

Figure 14.Opening with vertical SE

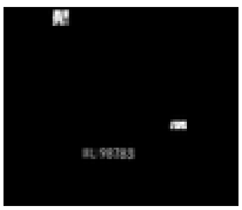

Figure 15. ROI

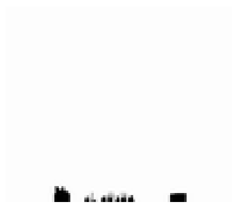

Figure 16.Vertical projection of ROI

D. ROI Analysis

In this paper, our task is to find out the region that contains the license plate from ROI. Mining the features of license plate in China, we discover that the license plate is composed of 7 characters (including a Chinese character) whose dimension (width, height and spacing) is fixed. Ratio of width and height is also constant. An eight-connected component extraction algorithm [11] is used to count the number of characters, but on considering that the factors such as the first Chinese character may not be connected and the tilt angle of shooting is about in the range of $-15^0\sim+15^0$, we employ vertical projection combined with thresholding to get the number of components of ROI (shown in figure 16). If the number is between 6 and 8 and the ratio of width and height of ROI is between 2.8 and 3.5, we believe that the license plate is obtained, if not, we will make another horizontal projection for the ROI satisfying the conditions. According to the above, we choose the lowest ROI as the license plate (Figure 17).

Figure 17.Extracted license plate region

IV. EXPERIMENTAL RESULTS

In order to check the availability of our proposed algorithm, we do the experiment repeatedly with four hundred car images and VS2003. Some of the car images are taken by us and some are from Internet, and they're different in size, position, camera angle, illumination environments, and resolution or vehicle type. The distance between camera and car considered is not fixed. The accuracy of license plate extraction is up to 98.1%. The result is inspiring. Some of the results of our experiment are shown in Figure 18.

(a) Simple test images(good illumination and contrast)

(b)Complex test images(askew, car body with rich vertical edges,obscure, in dark or sunshine, low contrast license plate shares similar colors with car body)

Figure 18. Results under different conditions

V. CONCLUSION

In this paper, we propose an effective method for license plate extraction. Images of our test set are from various complex scenes. The position of License plate can be obtained through a sequence of steps including vertical edge detection, edge detection, mathematical morphology and ROI analysis.

The results show that the algorithm is robust and the rate of success is encouraging. But some images are failed owing to having the similar region with characters to the license plate.

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