Design Flow of Vehicle License Plate Reader Based on RGB Color Extractor

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***Abstract*— In the vehicle license plate reader system, the License Plate Recognition (LPR) is designed based on machine vision technology without any direct human intervention. This paper presents an efficient LPR technique based on the RGB color extractor. The proposed method is capable of recognizing alphabets and numeric characters on the license plate in real-time. This technique has been tested with a large number of images in order to analyze its performance. The tested images are captured from the front and rear of the vehicles under different conditions, including different angles, luminance, and weather conditions. With the real-time test results shown in this paper, we obtain 98.5% accuracy for character extraction and 95.1% accuracy for character recognition using this technique.**

I. INTRODUCTION

In recent years, License Plate Recognition (LPR) has become one of the key technologies for high-speed vehicle inspection, road security, reducing rate of vehicle-related crimes, and the management of road traffic and parking lots. For security reasons, the vehicle database has been built favoring LPR techniques. This involves enhanced security enforcements and investigative capabilities, ability to expand collection of relevant data, expedite the time consuming process of comparing vehicles' license plates with the list of stolen and vehicles of interest. LPR also plays an important role in the Intelligent Transportation System [1]. The three sequential steps for LPR are: Locating license plate in a vehicle; Character extraction; and Character recognition.

In this paper, we present the design of an enhanced LPR technique which has improved edge detection and mathematical morphology to locate the license plate area. Further, we discuss the development and utilization of a better method called RGB color extractor to perform character extraction, overcoming the complex backgrounds of the license plate. The result of this technique is more accurate and efficient when compared with the traditional global threshold methods. Here we identify the characters based on template matching method [2]. After the character extraction, the result obtained directly affects the character segmentation, efficiency of character recognition and the efficiency of the system. The character extraction from complex scene technique is considered as the basis and prerequisite for the entire LPR system. The accuracy of this technique would affect its subsequent processing smoothness and hence it is also a key technique and one of the difficult stages in the license plate recognition system [3], [4]. The design flow for the developed system is shown in Figure 1.

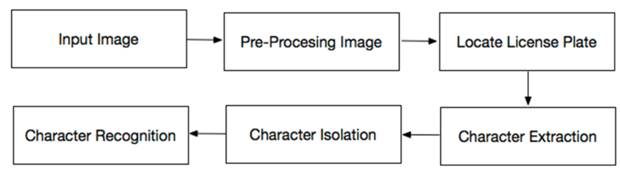

Figure 1. License Plate Reader Design Flow

II. IMAGE PRE-PROCESSING

Before the extraction of the license plate characters from the complex scene, we need to locate the license plate from the captured image. An algorithm based on morphological operations with an adequate threshold value and pixels statistics, which is sensitive to specific shapes and colors of the captured image has been developed for this purpose. Most of the localization process of the license plates is achieved by this algorithm. It is a better performing algorithm for pre-processing to extract the license plate in the images with complex background [5].

The first step is to convert an RGB image into a two color channel grayscale image. Mid-filter processing is then applied for the effective removal of unexpected noise. This process aims at increasing and improving the visibility of the image. Then we crop the image and this recognition process extracts the smallest rectangle that contains the edge of the license plate and license plate itself. Since the surrounding of license plate is not important, the cropping process significantly increases the speed of image processing [6].

A. Edge Enhancement and Edge Detection

Edge enhancement is a technique in image processing to make the image contour more prominent. The image edge enhancement technique calculates the difference values of each pixel and the neighboring pixels. This is achieved to enhance the image edge and highlight the license plate.

After enhancing the image, the system utilizes the Robert Operator [7] to detect the contour of the objects in the image. The Roberts Operator is one of most common operator templates [8]. It is a 2x2 convolution kernel, as described in Equation 1. Calculated results shows an edge magnitude picture.

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$$G_y = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \qquad G_x = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \tag{1}$$

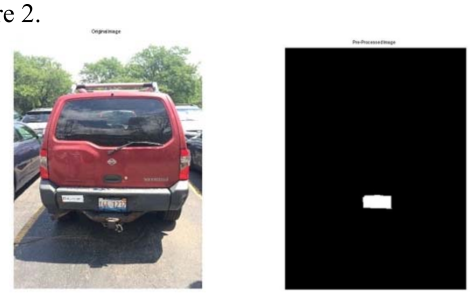
Since it detects the edges based on the difference between two adjacent pixels in a diagonal direction of the approximate gradient amplitude, the effect on the vertical is greater than on the diagonal edge. The resulting gradient magnitude G and orientation Θ approximations are computed as described in Equation 2.

$$\Theta = arctan\left(\frac{G_y}{G_x}\right) \tag{2}$$

B. Morphological Operations of Dilation and Erosion

After edge enhancement and edge detection, there are too many interferences and small objects in the image which result in a low recognition rate. Especially when the background disturbance appears as masses, it has far more effect on the procedures of the image recognition.

We implemented basic morphological operations to enhance the desired parts and eliminate the interferences. Assuming that *A* is the structural elements, *f* is the original image, and *m* is the signal shift, so *f* by *A*'s dilation is treated as $f \oplus A$, which is defined as: $f \oplus A = \{\mathrm{m} | [(\widehat{\mathrm{A}})_{\mathrm{m}} \cap \mathrm{f}] \neq \emptyset\}$; and A by f's erosion is treated as $f \ominus A$, which is defined as $f \ominus A = \{\mathrm{m} | (\mathrm{A})_{\mathrm{m}} \subseteq \mathrm{f}\}$; Open operation is the operation dilation after erosion of image, it is defined as $f \circ A = (\mathrm{f} \ominus \mathrm{A}) \oplus \mathrm{A}$. In this paper, we initially describe the techniques to enhance and brighten the image for the treatment. After this procedure, eliminating the small regions is achieved by setting a threshold of the area of the regions in the image [9]. The pre-processing result is shown in Figure 2.



(a) (b)

Figure 2. Pre-Process Image for Locating License Plate (a) Original Image; (b) Pre-Process Image

III. LOCATE THE LICENSE PLATE AND ROTATION

A. Pixels Statistics

Using the pixel statistics methodology, we can extract the license plate area by comparing the different number of pixels in the wanted area.

Since the background color of the license plate is white, all white pixels in a line and the average pixel value have a small difference. We consider that this line is a line the license plate and hence we obtain the license plate region.

In addition, the determined license plate area both in the X and Y directions helps in correcting the license plate area [10] as shown in Figure 3.

(a) (b)

Figure 3. License Plate Extraction (a) Processing Region; (b) License Plate Extraction

B. Image Rotation

Sometimes when the license plate is extracted, we face tilt issues. In order to acquire accurate results from the extracted license plate image, Hough Line transformation is implemented for tilt correction. The Hough Line transformation realizes the recognition of the global patterns in an image space by recognition of local pattern in a transformed parameter space, especially in straight lines. The main idea is to find curves with a proper parameter in parameter space by parameterizing straight lines.

After implementing the Hough Line transformation, we can obtain certain angle of license plate extracted from the previous step. Then, we rotate the image to a certain angle where the tilt exists. Image rotation is performed by computing the inverse transformation for every destination pixel. Output pixels are computed using bilinear interpolation. RGB image are computed by evaluating one color plane at a time. The following equations shows the principle of the rotation [11].

Before rotating:

$$\begin{cases} x_0 = ncos(\alpha) \\ y_0 = nsin(\alpha) \end{cases} \tag{3}$$

Matrix form:

$$\begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_0 \\ y_0 \\ 0 \end{bmatrix} \tag{4}$$

After rotating:

$$\begin{cases} x_1 = ncos(\alpha - \theta) = x_0 \cos(\theta) + y_0 \sin(\theta) \\ y_1 = nsin(\alpha - \theta) = -x_0 \sin(\theta) + y_0 \cos(\theta) \end{cases} \tag{5}$$

Inverse operation:

$$\begin{bmatrix} x_0 \\ y_0 \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} \tag{6}$$

After the tilt correction, we obtain the improved preconditions for further processing. Figure 4 shows an example of a license plate image with tilt correction.

(a) (b)

Figure 4. License Plate Rotation (a) License Plate Extraction; (b) License Plate Adjustment

IV. License plate Characters extraction

We use the Illinois license plate as an example to design the system. The background of Illinois License Plate is complex and includes the dealer information on the frame, the slogan of Illinois state, the portrait of President Lincoln, and multiple background colors consisting of white, light blue and dark blue. In order to extract and segment the characters from the complex background, we compare different methods until we get a better result for further processing.

A. Global Threshold Method

Thresholding is one of the widely used methods for image segmentation. It is useful in differentiating foreground from the background. In this paper, at first, we extract the characters by using Otsu method [12]. It aims at selecting an optimal value of the discriminant criterion, known to maximize the separability of the images in gray-level. It utilizes only the zeroth and the first-order cumulative moments of the gray-level histogram which extends to gain multi-thresholds. It is also based on the interclass variance maximization, and the result is shown in Figure 5.

(a) (b)

Figure 5. Otsu Thresholding Method (a) Original Image; (b) Otsu Processed Image

From the result shown in Figure 5, the background of the license plate is too complex and it is difficult to find a proper threshold value. The results and processing time are still not as good as expected. This lead us to find an alternative method to extract the characters from the license plates.

B. RGB Color Extractor

RGB color image has three channels, red, green and blue. Those three colors can be combined in various proportions to obtain any color in the visible spectrum. Levels range from 0% to 100% of full intensity of those three color channels. Each level is represented by the range of decimal numbers from 0 to 255. The total number of variety colors is $256 \times 256 \times 256$ or 16,777,216 different colors.

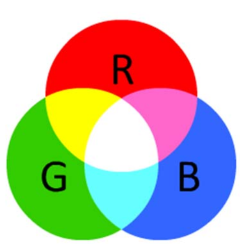


Figure 6. RGB Color Space [13]

The most critical and difficult part of the RGB color extractor method is to strictly define rules for determining RGB colors. According to the rule of extraction, when the color component of an RGB color is obviously not less than the other components, the pixels are regarded as a color, setting a threshold to determine and control the condition for color selection. We have the default extraction threshold value as 0 to maintain the integrity of the picture. In order to obtain the pure color, we appropriately increase the threshold value. We then set a gray photo mask to make the unwanted parts gray The advantage of this method is to eliminate the undesired information and to improve the calculation speed. Based on the results presented later in the paper, this method proves to be efficient and accurate. For example, when we implement the method on Illinois license plates (based on the feature of license plate we use), the color of main characters of the license plate is red. Thus, we use red mask with a proper threshold value to extract the characters, the result is shown in Figure 7.

(a) (b)

Figure 7. Extraction Based on Red Extractor (a) Original Image; (b) Red Pass Image

After extracting the characters from the license plate, some basic image processing methods are implemented such as gray scale image filtering; image binarization; morphological operation; elimination of unwanted small regions based on the ratio between perimeter and area for further processing [14].

V. Reading Characters

A. Character Isolation

Now that we already have the characters from the license plate, we are required to isolate the characters before we do the recognition. Here we use a particular method to find the continuous block of the characters. If the length is greater than the threshold value, it is considered as two characters, so we split and isolate them [15]. The design flow is shown as below in Figure 8.

B. Character Recognition

At present, the popular algorithms based on OCR are template matching and artificial neural networks. In this study, since the main features of template matching is simple, it is flexible to deal with the imperfect and smudged characters with a high recognition rate. Based on these features, we select the template matching algorithm to perform the character recognition. The basic procedure based on template matching are: binarization of recognized characters; shrinking the size of the characters to the size of the database template; template matching by subtracting extracted characters with all templates to find the result with maximum value of 0; and finally choose the best match as a result [16], [17].

We designed the template library based on the characters on license plate of the United States with specific shapes and forms. Figure 9 shows the template of the characters and the final result is shown in Figure 10.

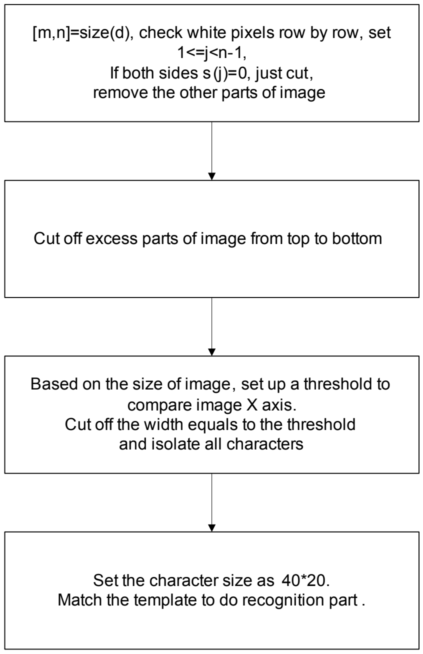


Figure 8. Design Flow for Character Isolation

Figure 9. Characters Template

Figure 10. Character Recognition Result

The recognition success rate is about 95% which is not as good as it could be. Since we use OCR system, we still have a few problems such as insufficient differences between some letters and digits for the computer to recognize. For example, digit “0” and letter “o”, digit “5” and letter “s” may be difficult to differentiate. Thus, we utilize the Tesseract tool [18] which is an open source optical character recognition engine. This helps in training the recognition process from the extracted characters to convert them to a text which will be easily recognized by computer. Since the adaptive classifier from the Tesseract tool has received some training data, the extracted characters can be converted to text and recognize correctly.

VI. Experimental Results and Discussion

We implemented RGB color extractor on different types of license plates. Over 225 color images with the resolution of 2448*3264*80 pixels taken by iPhone 5s camera are used in this experiment. The test images are captured from the front and rear of the vehicles under different conditions such as different angles, different luminance, and different weather conditions. Although the algorithms were optimized for the Illinois License plate, it can be easily extended to recognize other states’ license plates of other states of the United States. The performance of reading license plates from other states is also well satisfied. The test results are shown below in Table I, and the success rate is close to 100% which indicates this method is relatively efficient and accurate at extracting the characters with an encouraging result.

Table I. Character Extraction and Recognition Experiment Results

Total Vehicles Images	Characters Extraction	Successful Recognition
225	222	214
Percentage (%)	98.5%	95.1%

From the results shown in Figure 11, (a) and (b) are tested under the different luminance conditions, and work perfectly. (c) and (d) are tested under different angles from capturing the pictures and the results are satisfied with the requirement. (e), (f), (g) and (h) show the result of using a different RGB color mask to extract the characters which are perfectly extracted regardless of the difficulties including the frames, the stickers, the scratches on the license plates. (i) is tested under the condition where we have other vehicles in the picture and it also works flawlessly.

VII. Conclusion

In this paper, we proposed a simple and efficient technique for character recognition of the vehicle license plate based on RGB color extractor. The RGB color extractor is a standard tool in image analysis that allows us to extract the color information for pre-processing in this technique. The algorithms that we use in this paper can accomplish character recognition accurately. The experimental results show that the proposed technique is effective and functional. However, there is room for improvement in this algorithm since it does not work effectively in situations under dark lights and errors from different shapes of the characters we extract. But overall, this will be the direction of further research.

Figure 11. Results Based on Proposed Methods

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