# Two-row License Plate Extraction Based on CIELab Color Space in a Digital Image

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***ABSTRACT:*** *A vehicle license plate recognition system extracts plate information from a digital image through image processing technology. License plate extraction (LPE) is the premise and key concept of license plate recognition systems. In China, two-row license plates are yellow and dirty. Thus, a novel license plate extraction method based on CIELab color space is proposed in this paper. The method involves transforming a digital image from RGB color space to CIELab color space and using the b and a channels of CIELab color space to obtain the yellow areas of the digital image. Morphological operations are implemented to filter out noise and identify the license plate candidate areas. Lastly, texture features are utilized to locate the real license plate areas. Experiments indicate that the proposed method makes full use of digital image information to rapidly extract two-row license plate areas in a complicated environment.*

**Subject Categories and Descriptors**
**I.2.10 [Vision and Scene Understanding]:** Image Analysis, **I.4.10 [Image Representation]**

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## 1. Introduction

License plate recognition technology has been a popular research topic in recent years. Digital images contain a wealth of information that can help us make better use of license plate features to locate the license plate areas. China generally has one-row and two-row license plates. One-row plates are for cars, and two-row plates are for trucks, buses, and so on. Compared with one-row license plates, two-row plates are more difficult to locate in an image because of their special construction. This paper proposes a two-row license plate extraction (LPE) method.

Many LPE methods have been proposed [1–3]. Othman Khalifa [4] employed the Sobel operator to detect image edges and combined texture features to locate the license plate. This method is effective but exhibits poor performance in complex environments and dirty plates with fuzzy edge features. Gang Li [5] proposed a yellow license plate locating method based on an RGB color model and texture features. The experiments showed that the method is simple in principle, efficient, and fast but is inaccurate when the plate is dirty or the plate color is similar to that of the car body. C.Y. Zheng [6] proposed a license plate localization method based on CIELab color space. He utilized the characteristics of the image in CIELab color space, which can be a good solution to the problem of complex environment and different sizes of license plate images.

Clearly, each of the methods mentioned above has a problem. Thus, the method proposed in this study adopts

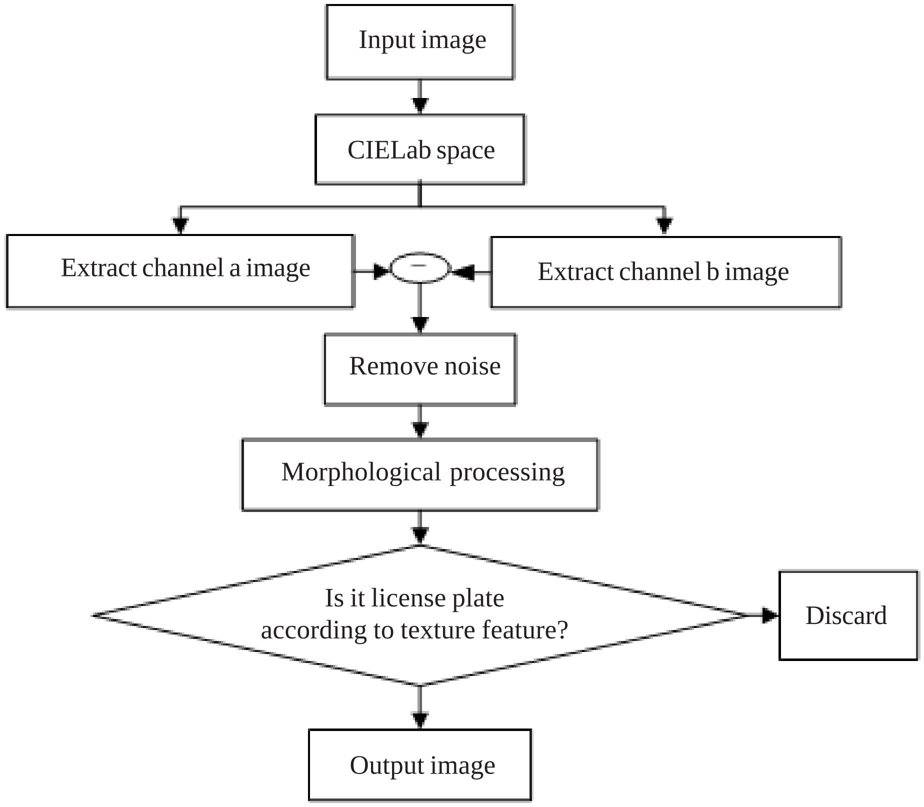

Figure 1. Processing flowchart

only their advantages. The proposed method involves the use of CIELab color space to extract color information, eliminate most interferences, and combine the texture features to locate the license plate. The experimental results show that the novel method is fast, efficient, robust, and adaptive.

## 2. LPE

### 2.1 Introduction of CIELab Color Space

A digital image is rich in color characteristics, which can be maximized. Unlike RGB and CMYK color space, CIELab color space is closer to the human vision. It is dedicated to the uniformity of perception, so it can accurately balance the color by modifying channels a and b and adjust the brightness/contrast through channel $L$. CIELab is not a common color space; it was established based on the international standards of color measurement proposed by the International Commission on Illumination (CIE) in 1931. It was officially named CIELab [7] in 1976. CIELab color space is not only a device-independent color system but is also a color system based on physiological characteristics. It is utilized to describe human visual sensing through a digital method. In CIELab color space, the L channel does not contain any color information and only includes lightness information; its range of 0 to 100 represents black to white. Channels a and b include color information; their range from –128 to 127 stands for green to red and blue to yellow, respectively [8].

### 2.2 Framework

A two-row LPE method is developed in this study. The yellow color of two-row license plates is special and different from that of one-row license plates. Thus, we make full use of the color information of the license plate. The framework of our method is shown in Figure 1.

### 2.3 Yellow Area Extraction

Generally, the input image is an RGB color image and needs to be transformed into CIELab color space. The following conversion formula [9] was utilized to convert RGB to XYZ space.

$$[X, Y, Z] = [MAT] \times [R, G, B] \quad (1)$$

Where $MAT$ is a $3 \times 3$ matrix as follows:

$$[MAT] = [0.412453 \quad 0.357580 \quad 0.180423; \quad 0.212671 \quad 0.715160 \quad 0.072169; \quad 0.019334 \quad 0.119193 \quad 0.950227]; \quad (2)$$

The formula to transform XYZ to CIELab color space is defined as:

$$L = 116 \times f\,[Y1] - 16 \quad (3)$$

$$a = 500 \times (f\,(X1) - f\,(Y1)) \quad (4)$$

$$b = 200 \times (f\,(Y1) - f\,(Z1)) \quad (5)$$

where $X1$, $Y1$ and $Z1$ are the $XYZ$ values after linear normalization. Their value ranges are similar to that of function $f$, which is from 0 to 1. Function $f$ is a correction function.


Figure 2 Extract yellow area: (a) The original image, (b) The yellow area of image with interference ($b_{im}(i, j)$), (c) The interference image ($a_{im}(i, j)$), (d) The the yellow area image ($c_{im}(i, j)$)

Where

$$f(x) = \begin{cases} x \wedge (1/3) & \text{if } x > 0.008856 \\ x \wedge (7.787 \times x) + (16/116) & \text{else} \end{cases} \quad (6)$$

The blue and yellow values are located at different ends of channel b. Thus, to obtain the yellow component image ($b_{im}(i, j)$), a proper threshold value $T_1$ should be set. This value can be obtained with a large number of experiments. However, the yellow area contains several red components, which is unfavorable for subsequent operations. Thus, we also employed channel a with threshold value $T_2$ to extract the red component image ($a_{im}(i, j)$) at the same time. Afterward, two component images were subtracted to remove most interference colors in the yellow area. Its mathematical description is expressed as:

$$b_{im}(i, j) = \begin{cases} 1, b(i, j) > T_1 \\ 0, b(i, j) <= T_1 \end{cases} \quad (7)$$

$$a_{im}(i, j) = \begin{cases} 1, \ a(i, j) > T_2 \\ 0, \ a(i, j) <= T_2 \end{cases} \quad (8)$$

$$c_{im}(i, j) = b_{im}(i, j) - a_{im}(i, j) \quad (9)$$

where $c_{im}(i, j)$ denotes the yellow area after the removal of most interferences. The experimental result is shown in Figure 2.

**2.4 LPE**

Apparently, the extracted yellow areas still contain plenty of noise. Eight-neighborhood method was utilized to remove the isolated noise, as shown in Figure 2. The eight neighborhoods of pixel $p(i, j)$ (Table 1) refer to the surrounding pixel points. If no adjacent pixels exist, we set 0 to substitute.

| | | |
|---|---|---|
| $(i-1, j+1)$ | $(i, j+1)$ | $(i+1, j+1)$ |
| $(i-1, j)$ | $(i, j)$ | $(i+1, j)$ |
| $(i-1, j-1)$ | $(i, j-1)$ | $(i+1, j-1)$ |

Table 1. Eight neighborhoods

A mathematical morphology operation was implemented to study the geometrical structure and shape of the image. The basic idea of a morphology operation is to use a probe ora structural element (SE) to detect the signal, remove noise, and eliminate rough edges. The composition of mathematical morphology is a set of algebraic operators of morphology. Common morphological operators include dilation, erosion, opening operations, and closing operations, which are defined as follows [10]:

Dilation: $F \oplus B(i, j) = max\{F(i-s, j-t) + B(s, t)\}$

Erosion: $F \ominus B(i, j) = min\{F(i-s, j-t) - B(s, t)\}$

Closing: $F \,.\, B = (F \oplus B) \ominus B$

Opening: $F \circ B = (F \ominus B) \oplus B$

In all the above operations $F(i, j)$ is a grayscale image and $B(i, j)$ is the SE. The shape and size of the SE plays crucial role in image processing and is therefore chosen according to the condition of the image and demand of processing.

Dilation can smoothen image edges and fill internal holes; however, it also expands the image boundary. Erosion can remove burrs and isolated pixels but makes the image shrink. We employed dilation and erosion operations to remove noise, smoothen the edges, and solve adhesion problems. After morphological operations, the license plate


Figure 3. Result of license plate detection

candidate areas were made available.

The selected candidate areas still contain several false license plate areas and thus need to be checked further. The texture features of the image, such as area, aspect ratio, and number of pixels in the connected domain, were utilized to identify the real license plate areas. The areas that were too small or too large were omitted according to the area of the connected region. The license plate areas (Figure 3) were then located based on the aspect ratio and number of pixels of the connected domain. All these operations were performed on the binary image to improve the speed.

| Method | Number | Success | Failure | Success Rate |
|---|---|---|---|---|
| [4] | 209 | 180 | 29 | 86.12% |
| [5] | 209 | 188 | 21 | 89.95% |
| [6] | 209 | 192 | 17 | 91.87% |
| Our method | 209 | 201 | 8 | 96.17% |

Table 2. Experiment results

## 3. Experimental Resules

To test the effectiveness of the method, 209 digital images captured in different environments, backgrounds, and pixel sizes were selected. These images have different amounts of light intensity and contrast. The proposed method was implemented on Matlab 7.10 and compared with the methods proposed in [4], [5], and [6]. The experimental results are shown in Table 2.

Among the compared methods, the proposed method achieved the highest detection rate (more than 96%) in complex environments and different light levels. From the verification results can be seen, the novel method effectively overcomes uneven light, dirty, and partial shade problems. A few detection failures occurred in the experiment because the texture features of the candidate areas are similar to those of the license plate. These detection failures were mainly due to the plate being dirty.

## 4. Conclusion

A simple but efficient LPE method was developed. The method is mainly for two-row license plates in China or yellow license plates for foreigners. The method is based on CIELab color space of a digital image, morphological operations, and texture features. The method was compared with other methods through numerous plate detection experiments. Many test images captured under different lightness levels, backgrounds, and times were used to test the efficiency of the proposed method. The experimental results show that the method can rapidly and accurately extract license plates in digital images. Future studies can investigate how to detect the accurate position for all types of color plates.

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