An effective license-plate detection method for overexposure and complex vehicle images

Hsiao-Yun Tseng
Department of Computer Science and Engineering National Chung-Hsing University Taichung, Taiwan 402, R.O.C
E-mail:s9556060@cs.nchu.edu.tw

Ching-Hao Lai
Department of Computer Science and Engineering National Chung-Hsing University Taichung, Taiwan 402, R.O.C
E-mail: phd9514@cs.nchu.edu.tw

Shyr-Shen Yu*
Department of Computer Science and Engineering National Chung-Hsing University Taichung, Taiwan 402, R.O.C
E-mail: pyu@nchu.edu.tw

Abstract

License plate detection plays an important role in license plate recognition (LPR) system. If license plate can be detected exactly, the character segmentation and recognition can be implemented more precisely and efficiently. In our observation, the illumination affects the result of detecting the license plate. The aim of this paper is to extract more than one license plate from an image and to obtain the license plates in the image which is taken under different conditions. The proposed method includes six processes as follows: transferring color to grayscale, image equalization, edge detection, checking black pixel ratio, plate verification and output license plates. The experimental results show that the proposed method can gain 94% accuracy in GetRatio *and 83% accuracy in* GetRight*.*

1. Introduction

There are lots of papers about license plate recognition (LPR) in the past two decades. Because the license plate recognition system is very useful for parking lot management, freeway ticketing systems, traffic law enforcement [6], stolen vehicles management, etc. There are three parts in a license plate recognition system: license plate detection, character segmentation, and character recognition. And the most important part is license plate detection. If the license plate can be detected exactly, the character segmentation and recognition can yield twice the result with half the effort.

In the past researches, many techniques which include to improve the hardware or to develop the software have been used to detect the license plate. About the hardware, a special camera that includes an optical principle of the sensing system was developed [3]. This sensing system with a wide dynamic range has been developed to acquire fine images of vehicles under varied illumination conditions. About the software, some different methods have been used, for example edge detection [5] [8], morphology operation [4] [5] [8], fuzzy discipline for color features [6], connected component analysis [9], measure edge density [5] [8], and image enhancement [7]. Otherwise, the features regarding license plate format include shape, color [6], height-to-width ratio [8], orientation [9], and the number of characters, etc.

Chen *et al*'s [8] used Sobel filter to detect the edges and the edges are dilated. Then black pixel ratios are checked; some continue black blocks are combined. Finally, the license plates are obtained from checking properties of license plates.

In the past, most of papers talked about license plate detection under simple background. However, some complex backgrounds like trees and signboards make license plate detection difficult in real environment. Besides, taking the pictures under different conditions such as sunny day, cloudy day, morning, or midnight will get different illuminations and this result will further affect the performance of the license plate detection. In this paper, we present how to extract more than one license plates from an image which is taken under different conditions and complex environment. This paper proposes some methods: image equalization, edge detection, checking black pixel ratio, and plate verification to extract all license plates from an image.

2. Proposed method

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The proposed method includes six processes as follows: transferring color to grayscale, image equalization, edge detection, checking black pixel ratio, plate verification and output license plates. (See Figure. 1.)

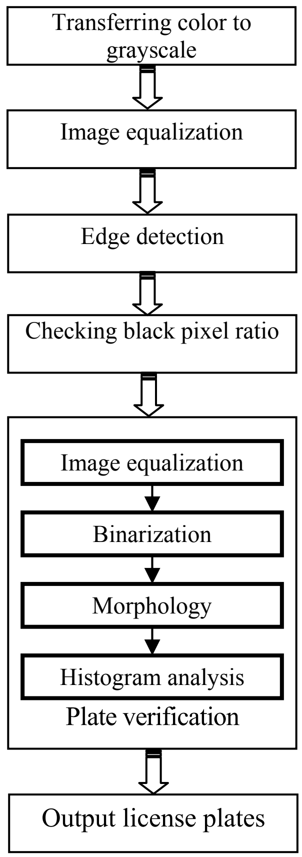


Figure.1. The overview of the proposed method.

2.1. Transferring color to grayscale

We generate the integer type pixel $GrayI_{i,j}$ and float type pixel $GrayF_{i,j}$ of a grayscale image from the corresponding color image by the following Formula (1) and (2) [1][2]:

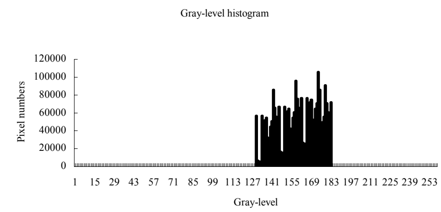
$$GrayI_{i,j} = 0.299 \times Red_{i,j} + 0.587 \times Green_{i,j} + 0.114 \times Blue_{i,j}, \quad (1)$$

$$GrayF_{i,j} = 0.299 \times Red_{i,j} + 0.587 \times Green_{i,j} + 0.114 \times Blue_{i,j}, \quad (2)$$

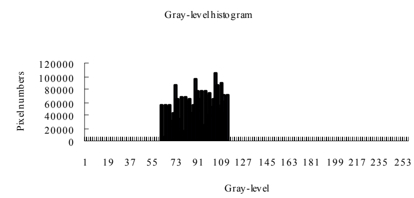
Where $Red_{i,j}$, $Green_{i,j}$, $Blue_{i,j}$ are the color values of the pixel at coordinate (i, j).

2.2. Image equalization

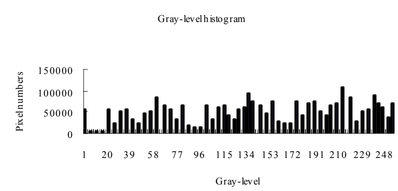
Different illumination of images affects the result of license plates detection. For example the part of license plate in an overexposure image is too bright to transfer enough black pixels. It will cause the following step can not find the license plates. (See Figure. 2(a).)



(a)



(b)



(c)

Figure. 2. (a) The gray-level histogram of a brighter image; (b) the gray-level histogram of a darker image; (c) the gray-level histogram of (a) and (b) after performing an equalization.

In general, image enhancement techniques allocate the histogram evenly. No matter the image is dark or bright, the results of histogram equalization are the same. The probability density function (PDF) of the input image level k is

$$p_r(k) = \frac{n_k}{n}, \qquad k = 0, 1, 2, \ldots, L\text{-}1, \quad (3)$$

where n is total number of pixels in the input image, n_k is input pixel number of level k, L is the number of gray-scale.

The gray-scale transformation function that is both single valued and monotonically increasing. [10]

$$S_k = \sum_{j=0}^{k} p_r(j) = \sum_{j=0}^{k} \frac{n_j}{n} \quad k = 0, 1, 2, \ldots, L\text{-}1. \tag{4}$$

After calculating gray-scale transformation function, the gray-pixels are re-allocated between [0, 255] by Formula (5).

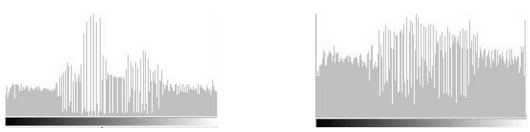
$$f(k) = 255 \times S_k \tag{5}$$

Because the traditional equalization only let each bin evenly distribute between the gray-level (0~255) and the number of bins in equalized histogram is invariable, many empty bins are appear between nonempty bins. It causes information losing when the gray-pixels are re-allocated. In order to solve this program, this paper proposes a novel equalization technique to fill up all empty bins using a linear interpolation technique. First, the probability density function (p_r) is calculated and the gray-level transformation function (S_k) is as traditional equalization method. In order to remain more original information, the integer type gray-level values $GrayI_{i,j}$ are calculated as Formula (1) and the float type gray-level values $GrayF_{i,j}$ are calculated as Formula (2). Then the re-allocated values of gray-pixel are calculated as Formula (6). The histogram of equalization mapping with linear interpolation likes Figure.3 (b).

$$newpixel = \begin{cases} 255 & if \quad GrayI_{i,j} = 255 \\ 255 \times tempf & if \quad GrayI_{i,j} \neq 255 \end{cases}, \tag{6}$$

$$tempi = (GrayF_{i,j} \times 100) - GrayI_{i,j} \times 100, \tag{7}$$

$$tempf = \frac{((100 - tempi) \times S_k + tempi \times S_{k+1})}{100}. \tag{8}$$



(a) (b)

Figure. 3. (a)Traditional histogram equalization; (b) equalization mapping with linear interpolation.

2.3. Edge detection

The Sobel edge detection method [10] is used in this paper to find the regions which have a high pixel variance value. Because there are characters in license plates, and they include abundant edges. We can use edge detection to find the important edges and remove some unimportant regions. These regions are the candidate regions for license plate location. The license plates can be found in candidate regions. In this paper, we use two 3 × 3 masks to calculate a gradient of a pixel by Sobel operators. Sobel operators contain two masks that detect horizontal and vertical lines. Then a threshold (T_1) is set for gradients. If a gradient is greater than the threshold, the pixel value is changed to 0 (black). Inversely, if it is smaller, the pixel value is changed to 255 (white). After edge detecting, a binary image can be obtained.

2.4. Checking black pixel ratio

After edge detection, the high gradient regions are reserved, but these regions may not contain the license plates. Because license plates contain lots of edge features, we can check the black pixel ratios to find the candidate license plates. This step includes three processes.

Firstly, the edge image is divided into many 32 × 64 blocks and their numbers of black pixels are stored in a (ImageHeight/32) × (ImageWidth/64) matrix M. Secondly, if the number of black pixels at (i, j) in matrix M is bigger than a threshold (T_2), each coordinate (32i, 64j) in edge image is the top-left corner of a candidate region. Thirdly, there is a drawback in above method. The location of license plate candidates has deviation. The position of each candidate needs to be adjusted by counting the number of black pixels in 16 × 32 points which regard (32i, 64j) in edge image as the center and the window size is 32 × 64. The method can get the whole 32 × 64 license plate from the maximum point located on the new top-left corner. Finally, after license plate candidates are detected. Some of them maybe are incomplete. The purpose of this step avoids extracting incomplete license plates. This scheme revises the size in vertical and horizontal direction respectively. In vertical direction, the black pixel ratio will be stored every time when the size expanded from one pixel to sixteen pixels. If the first ratio is bigger than original ratio, it continues to compare with next ratio. The expanded range will stop until the ratio decrease. (See Figure. 4) In horizontal direction, the ratio will be compared like vertical direction. In some cases, if the ratio is smaller than last ratio, it should compare with the next third ratio. When the next third ratio is bigger than present ratio, it will be a new beginning to compare with next ratios until the ratio decrease. The purpose of this part is to avoid getting incomplete license plate when the black pixel ratio decreases in the blank space between characters. (See Figure. 5)

After checking black pixel ratio, we can get license plate candidates in the image. But some real license plates are smaller than the license plate candidate and need to be revised their size again. In the last step, the proposed method executes the histogram analysis to eliminate the candidate areas that are not the license plate.

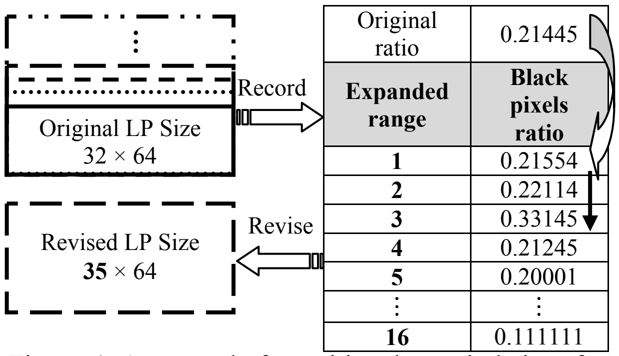


Figure. 4. An example for revising the vertical size of a license plate.

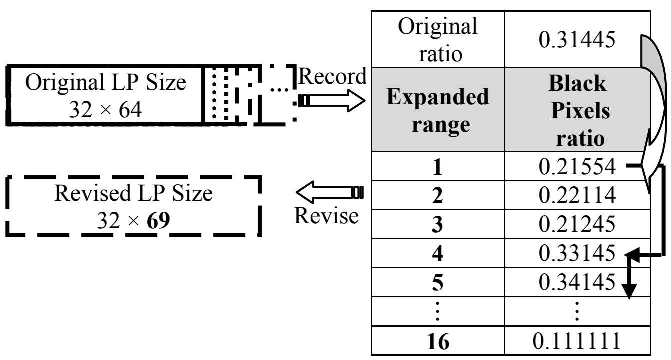
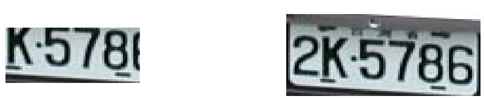


Figure. 5. An example for revising the horizontal size of a license plate.



(a) (b)

Figure.6. Revise license plate (a) before revise; (b) after revise.

2.5 Plate verification

The purposes of this step are revising the size again and executing the histogram analysis to eliminate the candidate areas that are not the license plate. It includes equalization, binarization, morphological process and histogram analysis.

In equalization, we use the same method as step 2.1. In binarization, the pixel will become 255 if the gray-scale pixel is bigger than a threshold (128). The pixel will become 0 if the gray-scale pixel is smaller than the threshold. Closing is a morphology-based operation. It is the main step to revise the size. The candidate areas get from step 2.4 exist the real license plate smaller than the candidate areas (see Figure. 7(a)). We can use this method to get license plates exactly.

We use closing operation, a morphology-based technic, to revise the size next binarization. There are two stages in closing operation. The first stage is dilation. The image will be scanned from left to right, up and down and the scan area is 3 3. If one of 8-neighbor pixel is white (255), the center point becomes white (255). The second stage is erosion. The image will be also scanned from left to right, up and down and the scan area is 3 3. If one of 8-neighbor pixel is black (0), the center point becomes black (0). (See Figure. 7(b))

After closing, some noises still exist in the image to interfere with extracting the white area (see Figure.7(c)). We use a 4-neighbor structuring element (see Figure. 8) to deal with this problem. If one of the 4-neighbor's pixel value is white (255), the pixel becomes white (255). The result shows in Figure. 7(d).

(a) (b) (c) (d) (e)

Figure.7. Morphology (a) original image; (b) result of closing; (c)some noises still exist in the image after closing; (d)result of deleting noise; (e) correct license plate.

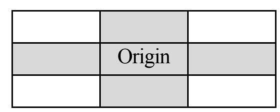


Figure. 8. A 4-neighbor structuring element.

After morphological process, the biggest white area in license plate candidates has to be extracted. The white area is scanned from the center point to four different directions in whole image. If the scanning meets the black pixel, the process will stop and the new coordinates will be record. If the height of the white area is bigger than the height of original candidate image divided by four and the width of the white area is bigger than the width of original candidate image divided by three, The proposed method refer to the new coordinates to get the license plate. (See Figure. 7(e))

Finally, In order to remove some false positive license plates, the proposed method analyzes the binarization histogram. This step utilizes the histogram feature, includes specific number of valleys, to eliminate the candidate areas that are not the license plates. If the height of a bin is smaller than the height of an image divided by three and smaller than the previous and next bins, then it is a valley. When the distance between two valleys is smaller than the width of an image divided by ten or bigger than the width of this image divided by five, an unsatisfied characteristic will be counted. The proposed method supposes that this is not the license plate and eliminate it if there are more than three unsatisfied characteristics in an image or the height of image is bigger than the width.

3. Experimental results

The proposed system has been developed by using JAVA. The size of images is 1024 × 768 pixels, and the image format is JPEG. To examine the ability of this research, we used two indexes are identified: *GetRatio* and *GetRight*. *GetRatio* is the ratio of extracted objects and license plates in images; *GetRight* is the correct ratio of the real license plate images extracted by this system. If the largest of the *GetRatio* and *GetRight* are obtained, the probability that the license plates in images are extracted is raised. *GetRatio* and *GetRight* are calculated by Formula (9) and (10).

$$GetRatio = \frac{EL}{RLN} \times 100\%, \tag{9}$$

$$GetRight = \frac{EL}{ELN} \times 100\%, \tag{10}$$

where *EL* is the number of extracted actual license plates, *RLN* is the number of license plates in the image and *ELN* is the number of license plate candidates.

The proposed method uses 10 images to test the system. Image A - F are taken under normal illumination and Image G - J are overexposure images. Image A, includes four license plates and we extracted four license plates and two other objects. Image B - D, include one license plate and we exactly find it. Image E, includes one license plate, and it is too oblique to reserve complete license plates. Image F, includes two license plates and the background is too complex so we extracted two license plates and four other objects. Image H - J, include 5 license plates and we can successfully find them. But still find some other objects. The results of our method are shown in Figure.9 -Figure. 13.

In Chen *et al*'s method [8], they can find the license plates under complex background, but they can not overcome overexposure issue. The accuracy of *GetRatio* and *GetRight* in Image G – J both are 0%. The accuracy of average *GetRatio* is 56%, and the accuracy of average *GetRight* is 69%. On the contrary, the accuracy of *GetRatio* is 94% in the proposed method. Our method can exactly extract the license plate under brighter illumination. The details are shown in Table 1.

4. Conclusion

The most important part in license plate recognition is license plate detection. If the license plates can be detected exactly, the character segmentation and recognition part can yield twice the result with half the effort. Our proposed method can overcome problems to find the many license plates under complex background. Our method uses six main processes as follows: transferring color to grayscale, image equalization, edge detection, checking black pixel ratio, plate verification and output license plates. The experiment results show that we gained 94% in *GetRatio* and the ratio of *GetRight* is 83%. It means the proposed methods have high performance to extract license plates but the problem of getting other objects besides license plates can be improved in the future. This research introduces the reforms of the following problems: only one license plate can be detected, picture with brighter illumination, and fixed license plate size.

Figure.9. Original color image (1024×768).

Figure.10. Grayscale image.

Figure.11. Equalization image.

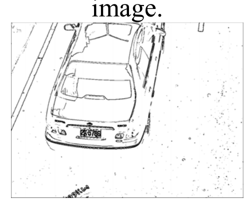


Figure.12. Edge detection image. ($T_1 = 200$)

Figure.13. (a)The results after checking black pixel ratio ($T_2 = 500$); (b) histogram analysis of plate verification; (c) results of plate verification.

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TABLE 1
Compare with Chen *et al*.'s method[8]

	RLN	*ELN*		*EL*		*GetRatio*		*GetRight*	
		Our method	Chen *et al*.'s method	Our method	Chen *et al*.'s method	Our method	Chen *et al*.'s method	Our method	Chen *et al*.'s method
Image A	4	4	3	4	3	100%	75%	100 %	100%
Image B	1	1	1	1	1	100%	100%	100 %	100%
Image C	1	1	1	1	1	100%	100%	100%	100%
Image D	1	1	3	1	1	100%	100%	100%	33%
Image E	1	1	1	1	1	100%	100%	100 %	100%
Image F	2	2	2	1	2	50%	100%	50%	100%
Image G	1	1	1	1	0	100%	0%	100%	0%
Image H	2	2	1	2	0	100%	0%	100%	0%
Image I	1	2	0	1	0	100%	0%	50%	0%
Image J	2	3	0	2	0	100%	0%	67%	0%
Total	16	18	13	15	9	94%	56%	83%	69%

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