AN APPROACH TO AUTOMATIC CAR LICENSE PLATE LOCATION BASED ON THE COLOR INFORMATION

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ABSTRACT

License plate recognition system (LPRS) is a complicated process that uses optical character recognition algorithm on images taken by digital cameras to read the license plates on vehicles for intelligent traffic systems. Yet, this paper is focused on the license plate location and character segmentation. The images have been taken by a 480×640 resolution digital camera under various lightning conditions with different backgrounds. License plate location and character segmentation has been performed by means of pixel analysis, image binarization, morphological operations, edge analysis and filtration. After the license plate location, the characters were segmented by using connected component analysis. The algorithm has been tested over a large number of images. Experimental results demonstrate a great robustness and efficiency of our method for small vehicles. 300 color images have been collected for this study. Of which, 24 images have been failed to locate the license plates present in the images; the license plate location rate of success is 92%.

1. Introduction

Besides traffic monitoring, there are many places that it is desired to control traffic circulation such as highway, electronic toll collection and parking access control systems [1]. Moreover, a stolen car can be found by traffic monitoring in electronic-police system [2]. At this point, the importance of license plate recognition systems (LPR) arises. There are two methods for LPR systems. One is based on microwave signal; the other one is based on license plate image. The first method is difficult and costly to implement, since each vehicle is supposed to have its own ID tag. Therefore such method is unsuitable in
many applications [1]. The second method (LPR) is an advanced technology that simply uses image processing techniques and optical character recognition algorithm on images taken by digital cameras to read the license plates on vehicles without human interference [2]. Since LPR systems are substituting the manpower, it is strongly expected that LPR will gain great importance in security in the near future. Recently, a nine-hundred-million-dollar-worth project called “PROMETHEUS: Program for European Traffic with Highest Efficiency and Unprecedented Safety” has been conducted in the area of license plate recognition [3]. Also in 1982, an England research team developed a similar project to PROMETHEUS, to find out robbed vehicles or expiration license plate from running vehicles on road [4]. These projects are great example showing the significance and the popularity of this research area.

Our research focuses on the license plate location and character segmentation from the rear view of vehicle. The proposed LPR system comprises three phases which are, license plate location, character segmentation and character recognition. Among these phases, license plate location is considered as the most important phase. It can be said that, the overall accuracy of any LPR system is formed by the accuracy of the license plate location. However, locating the license plate is a hard task to achieve since such a scene will be cluttered by items as shadows, bumpers, stickers etc. [5]. The difficulty can be due to the following reasons [1]:

1. The background is complex, such as there are some drawings on some license plates.
2. The different font and size of the characters of the license plate.
3. The illumination level can alternate according to the time image taken.
4. The dirty plates and shadow can reduce the success of the LPR systems.

In this paper, we present a novel and feasible algorithm to locate license plate and character segmentation for color images. The paper is organized as follows. In section I, three possible frames of which one hold the license plate have been determined by using pixel analysis. In section II, the exact frame which holds the license plate has been
selected among three candidates by using edge detection. In section III, the exact location of the license plate has been extracted by means of edge detection and morphological operation. Section IV deals with the character segmentation by using connected component analysis. Finally, experimental results and conclusions have been presented. The flow diagram of the proposed license plate location and character segmentation method is shown in Fig. 1.

Figure 1: Flowchart of the proposed method.

Most existing LPR methods are based on gray images but the color information is also an important factor to locate the license plate. The following assumptions are made in our method: the distance from the camera to the vehicles is constant; all characters of the license plate have a fixed width and the ratio between width and height.

2. Pixel Analysis

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License plates are normally located either between brake lights or below the brake lights. Therefore, the proposed method is designed to take advantage of this feature. In all cases, the brake lights must be red. Based on this knowledge, an operation for detecting red pixels has been performed. The desired pixels have been set to 1 as shown in Fig. 2(b). In order to eliminate the distinct red pixels found on the image, the statistical operation has been applied. Such that, the image has been scanned by $10 \times 10$ blocks, the blocks whose mean value are less than threshold value have been set to 0. Then, the local neighborhood relation of a pixel is found and the following operation has been adopted.

$$
T(x,y) = \begin{cases} 
1, & \text{if } T(x,y) = 0 \text{ AND } T(x,y + 1) = 1 \text{ OR if } T(x,y) = 1 \text{ AND } T(x,y + 1) = 0 \\
0, & \text{otherwise}
\end{cases}
$$

where the $T$ is the RGB image.

(a)The vehicle image                 (b)Desired red pixels            (c)The resulting image of (1)

Fig. 2 The whole process of locating red pixels

The result of the Equation (1) is shown in Fig. 2(c). After this model is constructed, the pixels which have common row index numbers with different column index numbers have been found. According to the column and row numbers, the maximum row and minimum & maximum column numbers have been found from the Fig. 2(c).

Where $T_{\text{min}}$, $T_{\text{max}}$, $T_{\text{max}}$ represents minimum column number, maximum column number and maximum row number respectively. Also note that $T_{\text{max}}$ is selected as 480. The image has been segmented into three sub-images according to the step sizes which are defined in equation (2) and (3). The equation (2) and (3) has been determined.
according to the relation between the sizes of the license plate with the distance between two brake lights.

\[
\text{step 1} = \frac{(T_{\text{max},c} - T_{\text{min},c})}{4} \tag{2}
\]

\[
\text{step 2} = \frac{(T_{\text{max},c} - T_{\text{min},c})}{6} \tag{3}
\]

The first, second and third segmented images are calculated as follows prior to knowledge the image size is 480 × 640. Figure 3(a), 3(b) and 3(c) shows the result of segmenting process.

![Figure 3](image)

(a) (b) (c)

Figure 3. Three possible license plate candidates.

2. Selecting the Correct Area for Locating the License Plate among the Three Candidates

In this section, the frame that contains the license plate area was selected from the three candidate frames obtained in the previous step. In this step, vertical edge information criteria was used to determine the frame that contains the license plate.

Images can have numerous edges but it is common to have vertical edges concentrated at the plate area for almost all of the vehicle images. Characters on the license plates are either printed with a light color on a darker background or with a dark color on a lighter background [6] [7], and vertical borders of the license plates make the biggest contribution to the vertical edges of the image among with the characters [8].

\[
S = \sum_{x} \sum_{y} V(x,y) \tag{4}
\]
where V is the image showing the vertical edges of candidate areas, x and y are the pixel locations. The image that returns the highest value of S is considered to be the image that contains the license plate. This method was applied to 300 images in the database; the license plate area was selected correctly for 297 images. Thus, the method has a success rate of 99% in selecting the correct frame that contains the license plate among three candidate frames.

3. Extracting the License Plate without Borders

The ultimate aim of all of the previous procedures is to extract license plate from the vehicle image. In order to segment all of the characters, the extracted image must contain only the license plate of the car without any borders or any other areas that does not belong to the license plate[9],[10].

After detection of the correct image that contains the license plate area, some preprocessing procedures were applied on the image using local standard deviation.

As it was pointed out before, characters of the license plate have the most vertical edges [6] and as a result of this, the standard deviation values of the pixels belonging to license plate characters have higher standard deviation values than the other pixels. Local standard deviation values of the image showing the vertical edges was calculated using a $79 \times 79$ neighborhood using the standard deviation formula as shown below:

$$\text{std} = \sqrt{\frac{\sum_{(x,y)} (I(x,y) - M)^2}{n-1}}$$  \hspace{1cm} (5)

where $I(x,y)$, $M$ and $n$ represents the pixel value, mean value and number of pixels respectively.

Standard deviation matrix was re-established by eliminating the pixels with smaller standard deviation values. As a result, for some images the exact plate area can be extracted, while for other images a smaller area around the license plate can be extracted.

It is not possible to extract the exact plate area for all the car images processed by only using the standard deviation values since the edges and standard deviation values differ too much for different images. Some of the reasons of these differences are color, illumination and background patterns of the car image. It is clear that, in order to establish a successful way for extracting the license plates for all of the images, further image processing methods are necessary. The following processes are used for extracting the license plate:
1. Closing operation for highlighting characters and to eliminate small artifacts,
2. Edge detection algorithms on the closed image
3. Detecting the location at which the border or the characters of the license plate first appear,
4. Extracting the license plate from the detected locations.

The schema showing the procedures for reducing the size around the license plate and extracting the exact plate is shown in Fig. 4.

![Fig. 4. Procedures for reducing the size around the license plate and extracting the exact plate](image)

Considering the size and shape of the characters in the license plate, the closing operation was performed using a ‘disk’ structuring element with the size of 7. The next step is to obtain the area around highlighted characters as a result of the closing operation. A windowing operation was applied with a window having a size slightly bigger than the size of the license plate. The reason of using a bigger window is the variations on the sizes of license plates in different images depending on the distance photos were taken. The window containing the characters area was chosen, and using the location of the window the original image was cropped. After the closing and windowing operations, the area around characters was further reduced and small artifacts in the plate area were eliminated, but these operations are not alone enough and sufficient for extracting the license plate so further image processing applications are necessary.
After the size of the original image was reduced using the closing operation, an edge detection algorithm is applied to the image. The edge detector used in this step was a ‘Canny’ edge detector with a threshold of 0.8. Since the sharpest edges appear at the characters and at the borders, this edge detector with a high threshold value, returns only these sharp edges in most of the images. Using the image showing the vertical edges, objects that do not belong to the plate area were eliminated and the exact plate area that includes the characters, without borders, was extracted. The operations and procedures used for this aim are listed below, in sequence:

- Detecting vertical lines at the left side of the image showing the vertical edges. If no vertical lines present, detecting edges at the left side of the image showing the vertical edges
- Detecting vertical lines at the right side of the image showing the vertical edges. If no vertical lines present, detecting edges at the right side of the image showing the vertical edges
- If present, detecting the first vertical line at the left side of the image which could be either the left border of the plate or the first character, depending on the image. If a vertical line is not present, detecting the location of the edge that is most likely belong to a character
- If present, detecting the last vertical line at the right side of the image which could be either the right border of the plate or the last character, depending on the image. If a vertical lines is not present, detecting the location of the edge that is most possibly belong to a character
- Determining whether the detected vertical line or the edges at the left side of the image belong to the border of the plate or belong to a character
- Determining whether the detected vertical line or the edges at the right side of the image belong to the border of the plate or belong to a character
- Extracting the license plate

Procedures to locate the license plate location are depicted in Figure 5.
Figure 6 and Figure 7 show the license plate with and without vertical lines after the vertical edge detection algorithm. The image is cropped and the exact plate area is obtained as seen in Fig. 6.

In Fig.7, vertical line belonging to the right border of the plate is apparent, but there are no vertical lines at the left side of the image. Edges belonging to characters are apparent at the left side.

4. Character segmentation

The main objective of this stage is to separate the characters from the license plate region found in step 3. It proceeds as follow:

4.1 Feature extraction. A set of conditions are applied for obtaining nothing but the characters from the license plate region. The license plate image taken from 4-6 meters distance has certain properties. The width and height value for each character has limitations as defined in equation (6) and (7).
\[ 10 < L < 40 \] \hspace{1cm} (6)  
\[ 5 < W < 20 \] \hspace{1cm} (7)  

where \( L \) (in pixels) and \( W \) (in pixels) represents length and width values, respectively. These constraints (6) and (7) are eliminating unnecessary objects and keeping only characters. This removal also includes upper border and lower border on the license plate region.

4.2 Filtration: Filtering is basically used to remove objects that do not satisfy specific features [11]. In the proposed approach, filtering is used to make the image sharper.

4.3 Connected component analysis: This part presents an algorithm for analysis of connected components on the license image. In this step each character has been labeled and a limitation has been developed based on prior knowledge as follows (8):

\[
\text{The object is a character if } \begin{cases} 50 < NL < 200 \\ \text{else not a character} \end{cases}
\] \hspace{1cm} (8)  

where \( NL \) (in pixels) represents the number of labels. It is as shown in Fig 9. Fig. 10 shows the segmentation results.

![Figure 8: The extracted license plate region.](image1)

![Figure 9: The segmented characters.](image2)

5. Experimental results

To evaluate the accuracy of our system, the method has been tested using Mathworks MATLAB® 7.11.0 over 300 colored images with a size of 480× 640 × 3. The images have been obtained from the rear of the vehicle under various illumination and weather conditions (sunny, cloudy… etc.). The test results are given in Table 1. The success rate is found as 92%. The test shows that 276 images were accurately segmented into
characters. The remaining 24 images were inaccurately segmented because of the unusual location of the brake lights.

<table>
<thead>
<tr>
<th>Total vehicle images</th>
<th>Extracted license plate characters</th>
<th>Unsuccessful extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>276</td>
<td>24</td>
</tr>
<tr>
<td>%</td>
<td>92</td>
<td>8</td>
</tr>
</tbody>
</table>

TABLE 1: The results of license plate character extraction.

6. Conclusions

In this paper, we have presented a new algorithm to segment license plate characters based on color information on vehicle images. The proposed algorithm has been tested over a database and stated a promising success rate. Our method is mainly focused on pixel analysis, morphological operations and connected component analysis.

7. REFERENCES


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