Morphology-based License Plate Detection from Complex Scenes

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Abstract

This paper presents a morphology-based method for detecting license plates from cluttered images. The proposed system consists of three major components. At the first, a morphology-based method is proposed to extract important contrast features as guides to search the desired license plates. The contrast feature is robust to lighting changes and invariant to several transformations like scaling, translation, and skewing. Then, a recovery algorithm is applied for reconstructing a license plate if the plate is fragmented into several parts. The last step is to do license plate verification. The morphology-based method can significantly reduce the number of candidates extracted from the cluttered images and thus speeds up the subsequent plate recognition. Under the experimental database, 128 examples got from 130 images were successfully detected. The average accuracy of license plate detection is 98%. Experimental results show that the proposed method improves the state-of-the-art work in terms of effectiveness and robustness of license plate detection.

1. Introduction

With the rapid development of public transportation system, automatic identification of vehicles has played an important role in many applications during the past two decades [2]-[3], [5]. For examples, the identification system can be utilized for managing park facilities, detecting stolen vehicles, controlling traffic volume, ticketing speeding vehicles, and so on. One of the most effective and useful identification methods is the license-plate recognition (LPR) through visual image processing.

A LPR system is mainly composed of three processing modules; that is, license plate detection, character segmentation, and character recognition. Among them, the task "license plate detection" is considered as the most crucial stage in the whole LPR system. In the past, a number of techniques [1]-[6] have been proposed for locating the plate through visual image processing. The major features used for license plate detection include colors [4], vertical edges [1], symmetry [6], corners, and so on. For examples, K. K. Kim *et al.* [4] used colors and neural networks to extract licence plates from images. However, color is not stable when lighting conditions change. The major problem in these approaches is the used features depend strongly on the intensity differences between the extracted license plate and car colors, which are not stable at different changes of lighting conditions and view orientations.

This paper tackles the problem of detecting license plates from visual images, and presents a novel approach for identifying the plates based on morphological operations. The proposed system consists of three main stages. In the first stage, a morphology-based technique is designed to locate possible positions of license plates. Since a license plate is a pattern with high variations, the features used to locate the plates should be robust to the changes of lighting conditions and view orientations. The morphological operations are used to extract the contrast features within a license plate as the important cues to extract license plates. The contrast feature is invariant to several geometrical transformations like car color, camera translation, rotations, and scaling. Therefore, the proposed method works stable under different image alterations. In the second stage, due to noise, a license plate cannot avoid being segmented into pieces. Therefore, a procedure must be developed for reconstructing an intact plate in event it erroneously becomes segmented during the extraction process. The recovery algorithm is cluster-based and thus invariant to different geometrical changes. The last stage of the proposed system is to perform plate verification. In this step, each plate candidate is verified according to the number of characters appearing in the candidate, which can be extracted from the character analysis algorithm. Once the set of registration characters has been extracted, a standard optical character recognition system can be applied soon for vehicle identification.

The proposed license plate detection technique can locate multiple plates with different orientations. In addition, the proposed segmentation process can significantly speed up the subsequent plate recognition since less than five candidates are extracted. In the experiments, 130 cluttered images including different lighting and orientation variations are used to test the effectiveness of the system. 128 plates are successfully located and thus the accuracy rare of detection is approximately 98%. In average, the proposed approach requires less than 0.5-second to finish the detection task. Experiments show that the proposed method is a great improvement in terms of effectiveness and robustness of license plate detection.

2. Overview of the Proposed System

The paper presents a technique for automatically detecting license plates from complex scenes. Fig. 1 is the

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flowchart of the whole system. The proposed system is composed of three major parts: feature extraction, detection of license plate candidates, and license plate verification. Each part is described in the following sections.

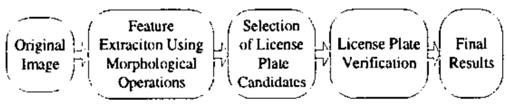

Fig. 1: Flowchart of the proposed system.

3. Feature Extraction Using Morphological Operations

It is known that a license plate is a pattern composed of several characters, which have high contrast changes to their background. In this paper, we use several morphological operations to find the high contrast area as important features to detect license plates. Before introducing the proposed method, some morphological operations should be introduced first.

Let $S_{m,n}$ denote a structuring element with size $m\times n$ where m and n are odd and all entries in $S_{m,n}$ are one. Let $I(x,y)$ denote a gray-level input image. Besides, let $\oplus$ denote a dilation operation and $\odot$ denote an erosion operation. According to $S_{m,n}$, we define several useful morphological operations as follows:

Closing Operation: $I\bullet S_{m,n}=(I\oplus S_{m,n})\odot S_{m,n}$;

Opening Operation: $I\circ S_{m,n}=(I\odot S_{m,n})\oplus S_{m,n}$;

Smoothing Operation E:

$$E_{S_{n\times m}}(I(x,y))=\frac{1}{mn}\sum_{i=-n/2}^{n/2}\sum_{j=-m/2}^{m/2}I(x+i,y+j)S_{n\times m}(i,j).$$

Then the whole procedure of morphology-based feature extraction is shown in Fig. 2. Firstly, in order to eliminate noises, a smoothing operation with a structure element $S_{7,7}$ is applied first. Then, the closing and opening operations with a structure element $S_{7,1}$ are performed into the smoothed image such that the images I_c and I_o can be obtained, respectively. In order to detect vertical edges, a differencing operation is further applied to the images I_c and I_o. All possible vertical edges can be extracted with a thresholding operation. It is known the vertical edges in a license plate are close and adjacent to each other. These adjacent edges can be connected together through a closing operation and then form a connected segment. Therefore, before thresholding, a closing operation is applied first to let all adjacent vertical edges form a connected region. Then a labeling process is executed to extract the license-plate-analogue segments. Then, a set of potential license plates can be obtained from a cluttered environment.

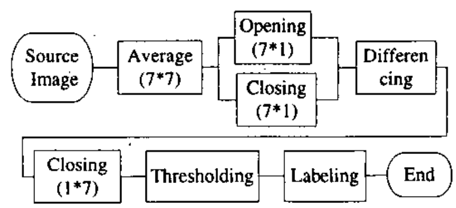

Fig. 2: Details of the proposed method to extract useful features for license plate detection.

4. License Plate Segmentation

After labeling, a set of potential license plates can be extracted from the images. However many incorrect license plates may be extracted from the cluttered environment. For instances, frames of windows, trees, edges among a set of books, etc. are frequently segmented as license-plate-analogue pixels. Therefore, some geometries and texture information are used first at this stage to remove these unwanted regions.

4.1. Candidate Extraction

Three criteria are defined here for eliminating impossible license plates. Let R denote the extracted plate region with the size $w\times h$. The first criterion is the density of the region R: $den=A/(h\times w)$, where A is the area of R. The second criterion is the ratio r between the width and height of R, i.e., $r=w/h$. The third criterion is that the size of a license plate should be larger than a fixed size, for example, 60×25. If the size of a license plate is not larger enough, the characters in the license plate will be too small for recognition. These criteria will significantly reduce the number of potential license-plate-analogue segments into few candidates.

4.2. License Plate Recovery

Due to noise or different lighting conditions, the extracted license plate region may not be a whole plate without fragments. For examples, in Fig. 3, the extracted region in (a) is a fragment of (b). Therefore, before verification, the incomplete license plate should be recovered first. A straightforward method to tackle this problem is to use a vertical intensity projection to calculate the average width and height of characters appearing in the fragment. Then, with the information, the whole plate is recovered from the fragments. However, this method is not stable under different skewing, scaling, and rotation of the extracted plate. In this paper, a cluster-based method is proposed for calculating the common geometrical properties of characters and then using the information to recover the whole plate. The method is robust to different skewing, scaling, and rotations of the extracted plate.

(a) (b)

Fig. 3: Result after license plate recovery.

Let R denote the extracted region with the size $w \times h$. For each character in R, a set S_c of character candidates can be selected though binarization and labelling. Then based on S_c, a clustering method is presented for calculating the common properties of characters to guide the verification. Let d_i denote the summation of distances of characters in S_c to the ith cluster and s_i denote a counter to record the number of characters belonging to the ith cluster. Initially, each character in S_c forms a cluster. Then, the algorithm to calculate the common properties of characters in S_c can be illustrated as:

Character Analysis(CA) Algorithm:

Step 1: Set d_i and s_i to be zero for all clusters.

Step 2: Let c_i be an element in S_c with size $h_{c_i} \times w_{c_i}$. For each pair (c_i, c_j), do the following steps:

Step 2.1: Calculate the distance between c_i and c_j as follows: $d_{ij} = \sqrt{\left(h_{c_i} - h_{c_j}\right)^2 + \left(w_{c_i} - w_{c_j}\right)^2}$.

Step 2.2: If $d_{ij} \le T_d$, calculate d_i and s_i by:

$$s_i = s_i + 1 \text{ and } d_i = d_i + d_{ij},$$

where T_d is a threshold to determine whether c_i and c_j are similar.

Step 3: Choose the index k such that:

$$k = \arg\max_{1 \le i \le N} (s_i + 0.5/(1+d_i)).$$

This attempts to find an index k such that s_k is maximized with a smaller d_k.

Step 4: Let w_k and h_k denote the sum of widths and heights of each character in S_c which is close to the kth cluster, respectively. Then, for each element c_j in S_c, if $d_{kj} \le T_d$, calculate w_k and h_k as follows: $w_k = w_k + w_{c_j}$ and $h_k = h_k + h_{c_j}$.

Step 5:The averages $\overline{w}_c$ and $\overline{h}_c$ of w_k and h_k can be calculated, respectively, by:

$$\overline{w}_c = w_k / s_k \text{ and } \overline{h}_c = h_k / s_k.$$

Step 6: For each element in S_c, if its width and height are close to $\overline{w}_c$ and $\overline{h}_c$, respectively, the character can be recognized as a correct character. Then, we can obtain the correct set $\hat{S}_c$ of characters from S_c and the number N_c of elements in $\hat{S}_c$.

After analyzing the common properties of characters in R, a method is then presented to recover the complete whole license plate from its fragments. Let l_R and r_R, t_R, and b_R denote the most left, right, top, and bottom coordinates of R in the x and y directions, respectively. In addition, assume the number of characters appearing in a standard license plate is a fixed number N_p. Then, the details of the license-plate recovery algorithm can be illustrated as follows.

License-Plate Recovery Algorithm:

Step 1: According to the CA algorithm, obtain the average weight $\overline{w}$, the average height $\overline{h}$, and the number N_c of correct characters in R.

Step 2: If N_c is less than N_p, enlarger R with the following steps:

Step 2.1: $l_R^{new} = l_R - (N_p - N_c) * \overline{w}$ and $r_R^{new} = r_R + (N_p - N_c) * \overline{w}$;

Step 2.2: if any pixel in S_c touches to the top of R, update t_R by $t_R^{new} = t_R - \overline{h}/5$;

Step 2.3: if any pixel in S_c touches to the bottom of R, update b_R by: $b_R^{new} = b_R + \overline{h}/5$.

Step 3: Binarize the new region R^{new}. Then, after labelling, a new set S_c^{new} of possible characters is obtained from the region R^{new}.

Step 4: Apply the CA algorithm to S_c^{new} and get the desired correct character set $\hat{S}_c^{new}$ and the new number N_c^{new} of characters.

Step 5: Let x_{left}, x_{right}, y_{top}, and y_{bottom} denote the boundary coordinates of $\hat{S}_c^{new}$ in the x and y directions, respectively. If $|N_C^{new}/N_p - 1| < 0.2$, R^{new} is recognized as a license plate with the boundaries x_{left}, x_{right}, y_{top}, and y_{bottom}.

4.3. Inclined Plate Rectification

Due to different camera orientations, it is difficult to guarantee an inclined license plate will not appear in the captured image. In order to recognize characters correctly, a plate rectification procedure is needed for compensating the inclined effect. Let R_P denote the inclined license plate. Let (x_c, y_c) denote as the center of R_P and w_R its width. In addition, let D_R denote as the height difference between the centers of the first and the last characters in R_P. Assume $R_P^{'}$ is the plate of R_P after rectification. For each pixel (*x*, *y*) in R_P', its intensity is compensated as follows:

$$R_p'(x,y) = R_p(x, y-(x-x_c)D_R/W_R) \qquad (1)$$

5. Experimental Results

In order to analyze the performance of the proposed approach, 130 images are used for testing. For increasing the complexity of the test database, the images are acquired at different lighting conditions including the time at a sunny or cloudy day, day time, night time, and so on.

Fig. 4 shows the detection results of cars when the colors between the license plates and their backgrounds are similar. In such case, edges between the plates and background are not clear. That will lead to the failure of plate detection for methods that consider the boundary of a license plate as an important cue for detection. However, our morphology-based method still works well. Fig. 5 shows the results when the license plates are inclined.

Fig.6 shows the cases when the input image with a smaller license. In this case, many small edge and textures appear in these images. However, the desired license plates are also successfully located by the proposed method. Fig. 7 shows the detection results when the license plates are darker or lighter.

Fig. 4: Results of license plate detection when the colors between the license plate and background are similar.

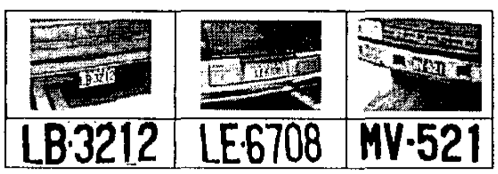

Fig. 5: Results of license plate detection when these plates are inclined.

For comparisons, the method proposed by M. Yu and Y. D. Kim [1] was implemented. Fig. 8 shows the comparison result. Since many vertical edges exist in this image, there are more than one hundred of candidates generated for verification and leading to the failure of detection. For our method, the wanted license plate is successfully extracted since only three candidates are generated in (c). The average accuracy of license plate detection is 98%. In other words, under the experimental database; only two examples got from 130 images are failed. The superiority of the proposed method can be verified through the preceding experimental results.

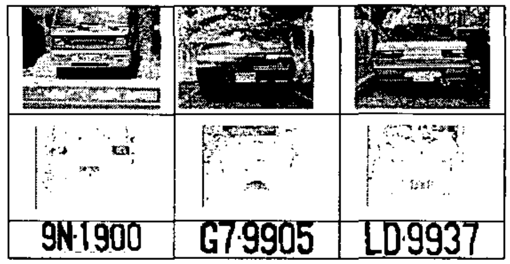

Fig.6 Results of license plate detection when smaller plates appear into the input images.

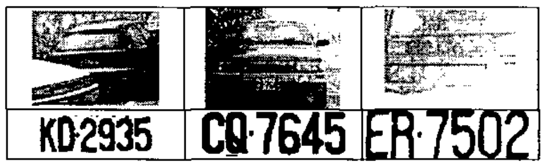

Fig. 7 The detection results when the lighting on the license plate is too light or dark.

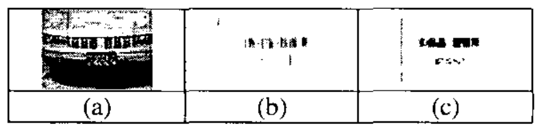

Fig. 8 Comparisons between the proposed method and the method proposed by M. Yu and Y. D. Kim.

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