An Efficient Methodology for License Plate Localization and Recognition with Low Quality Images

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Abstract. It is challenging to find an effective license plate detection and recognition method due to the different conditions during the image acquisition phase. This paper aims to develop a new accurate and efficient method based on color difference and SVM recognition model that yields better performance for vehicle images under low quality. The proposed method is tested with 200 images which involve many difficult conditions, such as low resolution, night-lighting, dirt, complicated background, and distortion problems. The experimental results demonstrate very satisfactory performance for license plate detection in terms of speed and accuracy and are better than the existing methods like edge detection or HSV color conversion method. The overall probability of localization is close to 100%, with a false recognition rate of 2%.

Keywords: Color Difference, Color Feature, Low Quality Image, LRP, Morphological Processes, SVM, Vertical and Horizontal Projection

1. Introduction

License plate localization and recognition (LPR) are an image processing technology used to identify vehicles by their license plates, which are the core subsystem of an intelligent transportation system. This technology is gaining popularity in security and practical traffic management services for vehicle information acquisition and storage, vehicle information search and comparison, illegal vehicle identification and alarm, criminal pursuits, highway surveillance, and toll collection, etc[1]. LPR algorithms generally consist of four processing steps [2]: 1) Preprocessing; 2) Detection and extraction of the license plate (LP) region; 3) Segmentation of the plate characters, and 4) Character recognition. Among them, plate localization is the most crucial stage, because the segmentation and recognition can perform well only based on the correct plate localization. Currently, the LPR still has big problems, whose true recognition rate relies on the quality of vehicle images captured from various sources. Constraints arise due to some environmental, illumination conditions, and plate deficiencies that provide some pictures of low quality. Such interferences which are affected by detection and recognition stages are summarized as follows:

i. Low resolution related to camera quality and the zoom factor.

ii. The plate may become abrasion, distorted, faded in color, or obscured by dirty during long-term use.
iii. Environmental variations like bad weather conditions (rainy, foggy, etc.), illumination condition (dusk or night-light contrast problems), or air pollution.

iv. the complicated background which may contain patterns similar to plates.

In the past and recent times, many efforts have been done to develop a robust LPR system, but they all have certain limitations in identifying LPs because of these interferences mentioned above. Aiming at the problem of weak anti-interference ability of the existing LP recognition algorithm, in this paper we try to propose an accurate and efficient method based on color difference and SVM recognition model that yields better performance for vehicle images having different difficult conditions. The most remarkable difference between our method and others is that we propose a new color difference model based on blue channels to complete the color conversion of the RGB space into a grayscale image while preparing for the detection phase. This conversion enhances the blue area and suppresses the non-blue area very well. With this innovation, many difficult features of LP problems mentioned above, like blurring, night-lighting, dirt, complicated background, are eliminated, and the intermediate errors of edge detection can be avoided. The pre-processing result can be more discriminative and lead to better performance.

The paper is organized as follows: The first section introduces our LPR system. The second section provides an overview of the related work about LPR systems. Section 3 presents the proposed method. The experimental results are reported in Section 4. Finally, this study is concluded with some useful recommendations and suggestions for future work.

2. Related work

In recent years, many scholars have invested a lot of energy in the research of LP recognition algorithm and come up with many specific methods. The key to these methods is the precise positioning of the LP and the accuracy of character recognition.

The most common solutions to LP localization are mainly through the implementation of texture feature [3,4], color feature [5], character feature [6], frequency domain feature [7] etc. The method based on texture feature works well for images with clean LPs and clear images, but for images with the poor distinction between foreground and background or complex background, it is easy to misposition the background as an LP. The method based on the color feature fails when the body color and LP color are similar [8,9]. The character-based method is difficult to guarantee the localization effect for LP deformation and deface. The calculation of the frequency domain method is large, often also need to combine a variety of methods to achieve better localization.

At present, the common methods of LP character recognition are template matching [10], statistical feature method [11], neural network method [12] and support vector machine method [13]. The template matching method is more adaptable for regular characters, and for the plate with some interference of defects and smudge or other situations. However, when the character image has rotation, zoom, tilt, and other distortion conditions, the recognition rate is relatively low. The anti-interference ability of the statistical feature method is insufficient and also the recognition effect will be greatly reduced in the case of the image by noise interference or image resolution is not high. The Multi-layered volume neural networks show a certain invariability to geometric transformation, lighting, etc. and have good generalization ability. However, training multi-layer neural network parameters will consume a lot of time, not suitable for large-scale implementation in real-time practice [14-16]. SVM algorithm is a machine learning method based on the minimization of structural risk [17,18], which shows many advantages in solving small sample, nonlinear, and Gauss pattern recognition, and has now been extended to multi-class classification problems.

3. The proposed method based on color difference and SVM model

The proposed approach for Chinese car number plates is described in this section. In China, heavy vehicles are assigned yellow LPs, light vehicles are assigned blue LPs, police cars are assigned white LPs, of which blue-and-white LPs are the most widely used, so this paper is mainly for blue LP
recognition research. Input to this system is the image of the car containing the plate and output is the actual characters of the plate. The image is captured in different conditions.

In the proposed method, as a first step, a pre-processing image has been done by converting the RGB image into the color difference space with the color difference formula of the blue pixels which is designed to enhance the LP area. Then this plate is located from the acquired image by using morphological processes, color features, and vertical and horizontal projections to extract the LP. After that, the next step comes in the progress of segmenting the characters individually for the recognition process. Then these characters are matched with our character database using the support vector machine (SVM) approach. The block diagram of the proposed system is depicted in Fig.1.

![Fig.1 Block diagram of the proposed system](image)

Since images have taken in different conditions that some of them might contain a lot of noise and small spikes, which will cause a lot of interference for subsequent processing, so intensity uniformization and noise reduction using Gaussian filters are necessary before the color space transformation process.

### 3.1. Changing color space to grayscale image with the color difference

There are different resolutions involved in vehicle images, with large resolutions often require more processing time. Therefore, the grayscale images are resized to the desired size for the output image. A regular method often uses a grayscale image by converting a color input image (24 bit) into a grayscale image (8 bit) as follows:

\[
    G (I, J) = 0.3 \times R (I, J) + 0.59 \times G (I, J) + 0.11 \times B (I, J)
\]

where \(I\) and \(J\) are any pixel inside a grayscale image, \(G\) is a grayscale image, and \((R, G, B)\) are three color channels of red, green, and blue for color images respectively.

This study, for the most common blue-and-white vehicles, uses a blue color difference calculation formula (2) instead of the normal one to highlight blue pixels, thereby suppressing pixels in other areas.

\[
    C (I, J) = B (I, J) - \min \{R (I, J), G (I, J)\}
\]

where \(C (I, J)\) is the pixel value of the coordinate point \((I, J)\) after the conversion, \(B (I, J)\), \(R (I, J)\), and \(G (I, J)\) are the pixel values of the red, green and blue channels, respectively.
The step of this conversion helps in enhancing the value of the blue area and suppresses the value of the pixels of the non-blue area. The pre-processing stage has a clear effect to reduce the unnecessary interference information from blurry, night-light, and complex background images, and Fig. 2c demonstrates the result of the blue difference process. A histogram equalization method is applied to the blue difference processing image to enhance the contrast condition (see Fig. 2d).

For ordinary blue cars, after the color conversion, it is clear that the brightness of the blue areas is significantly higher than the brightness of other areas in the image (see Fig. 2c and Fig. 2d). The brightness of the blue areas are the highest in the whole image, furthermore, the non-blue areas of the pixels are well suppressed, and the pixel value is close to 0. Compared to a simple grayscale image (see Fig. 2b), the edge of the LP area is highlighted, which is exactly what we need. In this way, the pre-processed grayscale map is more conducive to the next step of area extraction, increased the probability of successful detection of the LP area.

3.2. Morphological processes
A number of mathematical morphological processes are applied to remove all unrelated objects in the image. After color difference processing, the edges of the LP are significantly enhanced and the space between the characters is very small and faint. An open-close operation of the morphological process will be performed to connect the adjacent small blocks into a largely connected area. This operation, which is just suitable for the LP block connectivity, makes all characters connected into blocks to form the outline of the entire LP. Then a series of actions like smoothing boundary, clearing boundary objects, and removing small objects are followed to ensure accurate positioning of the LP area. Fig. 3 shows the filled areas which contain the LP for candidate selection after these pre-processing processes.
3.3. Plate areas extraction
As being described in the previous subsections, process 3.2 locates more than one candidate region (illustrated in Fig.3). To determine the correct candidate region which contains the LP will require the candidates to undergo some evaluation process. After finding the rectangular area of the image and plates correction, the analysis with a) color feature and b) vertical and horizontal projections are adopted to select the correct LP area successfully.

a) Color Feature Analysis: First, calculate the pixels of the entire matrix, and then record how many blue and white pixels in the matrix, and finally filter the LP candidate area roughly according to a certain proportion of the two types of pixels, determining the four vertices of the rectangular box by the color characteristics of LP background, and saving the picture.

b) Vertical and horizontal projection Analysis: Vehicle images are often noisy due to environmental factors. The histogram equalization is applied to make the image details clear, to enhance the purpose of characters, easy to the next step. The binary image which is got by Otsu’s global thresholding method is projected horizontally to get the threshold and histogram in the horizontal direction. The upper and lower boundaries of the character area can be determined by this operation. It is necessary to remove one pixel from the upper and lower edges of the LP in order to avoid affecting threshold judgment. Similarly, the image is subsequently projected vertically to find the threshold and histogram in the vertical direction, which determines the left and right boundaries of the character area. If the number of peaks in the vertical projection is greater than 6, the LP area can be extracted.

3.4. Character segmentation
The character segmentation, acting as a bridge between the LP extraction and character recognition section, is an operation of separating the LP area into individual characters. Chinese standard vehicle LP consists of 7 characters, with the first character in Chinese characters, the second character in English capital letters, and the next 5 in a mixture of capital letters and numbers. A single character is
45 mm wide and 90 mm high, with a 34 mm interval between the 2nd and 3rd characters. A small dot is in the middle of the interval, and a 12 mm interval between the remaining characters. Looking closely at these white characters which fall on a blue background on Chinese LPs indicates that thresholding will be a very convenient tool for the purpose of character segmentation. On the other hand, the LP localization module has already been working with the vertical projection images which are needed in the segmentation step. Thus, this results in the extracted LP are already in the desired form. To extract the characters on the LP will only require the location of the bounding peaks of each object in the chosen candidate region. Then, for each extracted bounding of character, the object with the maximum area is retained if there is still non-character noise in the area. All other objects are removed. Fig.5 illustrates the character segmentation process.

Fig.5 Character segmentation

3.5. Character recognition with SVM

The recognition of LP characters is a multi-category recognition problem whose character images have a total of 34 categories (the character “I” is not used in the LP system, and the character O and the number 0 are too similar to distinguish easily). SVM has been widely applied to classification and object recognition, due to its capacity to handle nonlinearly separable data. In this paper, the characters to be recognized, which are obtained from the image through the segmentation step, are recognized using SVM model. Firstly, in the training phase, the individual character pictures, which are converted to the same size, are imported into the training set in order to train the support vector machine model. The parameters and parameter range of SVM is related to the selection of the kernel function. In this paper, we choose the radial basis kernel function. Meanwhile, we optimize the parameters and feature vectors by performing cross-validation to find the best parameters for the SVM model during LP recognition. Next, in the recognition phase, the pixel values of character pictures are extracted as input to the classifier feature vector. We use the trained SVM license plate character classifier to make classification decisions for the real plates. It is worth noting that the first character should be recognized as a Chinese character, and the remaining characters are identified by letters or numbers. Finally, the results are output as shown in Fig.6.

Fig.6 Sample of successfully LP character recognition

4. Experimental results and discussion

This experiment is in the OpenCV environment, using Python language programming to implement the algorithm proposed in this paper. For low-quality vehicle images with low resolution, night-light, dirty, and so on, Fig.7 illustrates the outcome of recognition on these pictures. Comparatively, these images can’t get the right plate candidate areas with a method of edge detection or HSV color conversion method. From this, it can be concluded that the proposed method is better than the edge detection and HSV conversion method for the processing of low-quality vehicle pictures.

A total of 200 digital images have been used to test the proposed algorithm. An average of 98% in successful LP localization and recognition of complex outdoor images are recorded. The test data sets
are made up of all kinds of vehicle images in low resolution, varying illumination conditions, and complex background, etc. In a controlled environment, the accuracy of localization is close to 100%.

![Blurry image with low resolution](image1)

![Night light image](image2)

![Vehicle image obscured by dirty](image3)

**Fig. 7** LPR results in different situations
All the pictures are recognition correctly except the example of a blurry image (Fig.7a). It is observed that the blurry image unsuccessful recognition is a result of LP characters that do not have a clear contour, and Chinese characters are too blurry for even the human eye to recognize, so the machine cannot recognize them. Obvious solutions to this problem are to utilize high-resolution images or to simply ensure that the image is taken at a distance and viewpoint that ensures recognition successfully of the characters on the LP.

Compared with the conventional method, the whole process proposed in this paper does not only improve the speed of recognition but also improves accuracy. It has certain advantages to be specialized in low-quality vehicle image recognition effectively. The research has a certain practical significance and application value.

5. Conclusions
Aiming at the problem of weak anti-interference ability of the existing LP recognition algorithms, this paper proposes an accurate and robust LP recognition approach based on color difference feature and SVM model. Firstly, we use the color difference to highlight the blue areas in the whole image to find the possible LP regions as candidates. Secondly, we extract the true plate region by analysing the ratio of blue pixels and white pixels, and by the vertical projection of candidate regions. Finally, we use the trained SVM classifiers to identify LP characters.

The algorithm gives good results on our database. It has the advantage of high speed since having no complex calculation formula and also has good accuracy because the interference of rich edge information of body and background on LP can be avoided. The whole system is relatively robust to different kinds of difficult conditions vehicle images. It can solve the effects of insufficient night lighting, low picture pixels, and LP deficiencies such as deformation, fading, dirt, and blocking, etc. The next step is to further study the LP localization and recognition algorithm for other color LP such as yellow, green, and white so that it has better applicability.

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