The license plate recognition system based on improved algorithm

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Abstract. The research of this paper is based on the license plate location algorithm and Radon transform. The license plate location algorithm applies edge detection and morphological algorithm. The principle of Radon transform is adopting binarization processing for the selected global threshold and morphological processing for the license plate to segment the connected region, on the basis of the vertical projection of local areas and the character segmentation of connected areas. At the end of this paper, a character recognition system based on improved BP neural network is taken. It can overcome some difficulties that traditional algorithm confronts, such as slow in getting the optimal solution and easy to fall into the local minimum. Also, compared with existing methods, this method has a fast convergence rate and recognition speed and a high accuracy.

1 Introduction

Car license plate recognition technology \cite{1,2,3,4} (License Plate Recognition, LPR) is an important part of the Intelligent Transportation Systems (Intelligent Transport System, ITS), it can be widely used in traffic monitoring and management, vehicle safety and other fields, whose promotion will have an important and far-reaching impact \cite{5} on many aspects, such as, strengthening highways and management of urban roads, reducing traffic accidents and car thefts etc. The operating process is converting car images taken by cameras into digital images through image acquisition card, or using a digital camera directly to obtain the digital image, and then uploading the image to the computer, applying the license plate recognition software to locate and select, after that processing the selected licenses with character segmentation, and finally through the algorithm outputting the identified licenses. Simply speaking, the license plate recognition system mainly includes four parts: image acquisition, location, character segmentation and character recognition \cite{6,7,8,9}.

Currently, the traditional methods of the license plate location are: (1) based on the level grayscale characteristics \cite{10}. When the background noise of license plate image is relatively small good results may be gotten, but not vice versa. (2) based on the color information \cite{11}. This method has a fast operating speed and high accuracy, but when the plate’s color is similar to the characters’ color, the license plate positioning errors will increase. (3) based on edge detection \cite{12}. This method has a high accuracy for positioning, a quick response and can effectively remove the noise, but it is easy to omit something and the rate is slow. This paper proposes a fast location method which is based on edge detection involved in morphology operation, combining plates’ shape. It’s proven by practices to improve the detection rate.
When carrying out the license plate character segmentation, due to the angle’s change between the camera and the license plate, images may tilt, affecting the character segmentation. Currently the methods about the license plate are: (1) Hough transformation\textsuperscript{[13][14]} This method has a high demand on images, and calculation is large and complex. (2) Radon transformation\textsuperscript{[15]}; (3) the rotation projection method\textsuperscript{[16]}; (4) the method which is calculating the center points of each character connected domain on the license plate, and then fitting a straight line to get the incline angle of the plate\textsuperscript{[17]} (5) the algorithm which detects straight lines with random points\textsuperscript{[18]}; (6) the method which obtains local minima and local maxima characteristic point in the license plate character region and use projection to determine the tilt angle projection plate\textsuperscript{[19]} . Its precision will decline when this method is used in some complicated conditions. For instance, there are smudges or noises someplace.

About the mentioned methods above, Hough transformation method and the rotation projection method is more common, while this paper adopts Radon transformation for dealing with the inclination angle. And for character segmentation, the partial vertical projection is taken in order to achieve the extraction and segmentation of characters. For recognition, the most commonly used methods are based on template matching and neural network\textsuperscript{[20][21][22]}. According to composition features of the domestic license plates, this paper adopts BP neural network which is multi-layer feedforward neural network propagated in a single direction.

2 Implementation

2.1 The fast positioning method based on morphological operation and characteristics of license plates

Step1 Grayscale: In order to reduce the data dimensionality, we will usually convert colorful plate images into grey ones. Figure 2-1;

![Figure 2-1 Grayscale image](image1)

Step2 Median denoising: Generally speaking, there are various noises after step1. The main purpose of this step is to remove the random noise in the picture by using median filter;

Step3 Horizontal difference: As the horizontal veins of plate images is more multiple, we can give greyscale to a horizontal difference so that it can effectively detect the edge in the vertical direction, making the license plate positioning more accurate, shown in Figure 2-2.

![Figure 2-2 Image after the difference operation](image2)

Step4 Morphological operations: We do etching process by using the structure of square elements of size 15 on the image after step3 to eliminate minor interference, and then carry on its morphological closing operation: first step is inflated operation, and the next step is to do erosion operation by using the same size structural elements so that the license plate of the region can form a connected domain, shown in Figure 2-3.
Step 5: Connected domain processing: The position of image plates processed after step 4 may be in two or more domains, so you need to splice the close connected domains and treat them as one connected domain when seeking coordinates. For the vehicle license contains seven characters, we should take three lines from the middle of the plate, and its number of connected domain should be more than 7. If the number is 1, the location of the connected domain is the location of the license plate. If there are two or more connected domain, considering that the proportion of the plate’s side length is fixed, we should do binarization operation to the position of the plate. We will find the proportion of black and white dots is within a certain range, and we can do further screening, shown in Figure 2-4.

Step 6: Parameter tuning: In order to better locate, we need to adjust the parameters constantly. Here we select 60 known license plates which have fixed proportion of length and width to determine. When height is at interval(20,75), width is in range(110,300) , height / width is in range (0.13,0.32), that’s the plate’s position. After practicing, all 60 license plate image are successfully positioned. Specific positioning flowchart in Figure 2-5.
2.2 Tilt correction algorithm based on Radon transformation

With previous knowledge we know that the inclination of the license plate’s horizontal edge does not exceed a certain angle, as shown in Figure 2-6. The Radon transformation this paper takes is projection transformation which computer images show on the ray direction to develop a certain angle, in the X-axis projection, as shown in Figure 2-7.
Steps as follows:

Step 1: The license plate image after positioning Figure 2-1, doing edge detection with Sobel operator as Figure 2-9 shows;

Step2: Calculating binary edge image of the Radon transformation and finding the local maxima R as a tilt angle of frames in the image in Radon transformation matrix;

Step3: Using imrotate function to give the image after correction shown in Figure 2-10.

2.3 Character segmentation based on local vertical projection

There are many typical character segmentation algorithms, such as characters segmentation algorithm by means of Rough transformation and previous knowledge, fixed boundary segmentation method, projection segmentation method, and connected region segmentation method, etc. This paper proposes a partial vertical projection segmentation method on the basis of projection segmentation and connected region segmentation method. The partial vertical projection is to select a partial area of the license plate for projection, such as 1/2 plate area or 3/4 area. By selecting different local candidate region, adjusting gradually, we can avoid the character connection caused by the horizontal border or noise, making the results more accurate. The specific steps are as follows:

Step1: Doing vertical projection on the whole plate image with a pretreated stable connected domain, if the width of the sub-image blocks ranging within a predetermined threshold range (here the threshold recommendations set [5,28]), statistical communication domain region being 7, then proving splitting be right, returning;

Step2: Discarding the blocks whose width is less than the lower limit of 5, segmenting the blocks whose width is greater than the upper limit 28 by using vertical projection of 3/4 area, if the number of communication domain being 7, then correctly splitting split, returning;

Step3: Using the following regions, 3/4 area, 2/3 area and 1/2 area respectively, if the communication number being 7, splitting right, returning;

Step4: If the communication area is greater than 7, combining the connected domain with the smallest width with the next connected domain, subsequent connected domains correspondingly moving forward.

Step5: Finally, arranging each connected domain in order to obtain segmentation results.

As can be seen from the chart above, except seven clear communication domains, there are two smaller communication domains in the leftmost and rightmost areas, which is due to the impact of the border. When we choose the 3/4 area, we can remove the leftmost communication domain, but the rightmost communication domain can’t be removed; when we choose 1/2, we can remove the
rightmost communication domain. By this method, we can remove excessive connected domains and segment characters correctly.

2.4 Recognition Method Based on BP Neural Network

The result of the license plate recognition is that license plate character image is output into a text character, taking advantage of further processing of human visualization and computer. There are two artificial neural network algorithms: one is recognizing features and extracting characters, and then training the neural network distributor with the obtained characters; the other is to directly input the network image to be processed into the Internet, finish the features extraction automatically via the Internet and get the recognition results. The main task is to conduct targeted feature extraction and training based on the composition characteristics of the license plate.

2.4.1 BP Neural Network Model. BP (Back Propagation) neural network, the learning process of back propagation of errors, consists of forward propagation of information and back propagation of errors. Neurons on the input layer receive input information from the outside, and transmit it to neurons on the intermediate layer; the middle layer is the internal information processing layer, which takes charge of the information transformation. According to the demand of information changing, the intermediate layer can be designed as a single hidden layer or a multiple hidden layer; the information which the last hidden layer outputs to the input layer, after further processed, will complete the forward propagation process. The output layer outputs the information to the outside world and processes results. When the actual output and the expected output don’t match, the error back propagation process will be implemented. Errors pass the output layer, correct weights of each layer by the error gradient descent from the hidden layer to the input layer. The cycle process of information forward propagation and error back propagation is a process of constantly adjusting the weights of each layer, as well as the training process of the neural network. This process doesn’t stop until the network output error is reduced to an acceptable level, or the learning times are set in advance.

Here is a typical BP neural network structure:

![Figure 2-11 A typical BP neural network](image)

2.4.2 Experiment. After 2.3 section division processing operation there will be the character images of the same size. Then we carry out feature extraction, and take feature vectors that primarily show the training samples’ characteristics as the input of the BP network to train the constructed network. After that, we introduce the feature vectors of the samples to be identified into the trained BP network, and characters will be identified.

(1) Feature extraction
In this study, we used the way named 20 feature extraction. Firstly, the characters to be trained average 16 parts. Secondly, we take the proportion of every calculated white pixel point as former 16 feature vectors, and then take the white pixel points of two rows in the horizontal direction and in the vertical direction as the last four feature vectors.

(2) The structural design of BP neural network
According to the combination characteristics of numbers and letters on the license plate, it is that the first character is Chinese character, the second character is English alphabet, the third and fourth character English letters or numbers, the fifth to the seventh character both figures. In this paper, we construct four typical three layers of BP networks, and they are used to identify Chinese characters and English letters, numbers or combinations of English letters and numbers. All BP network structure has 20 nodes input, but the outputs are different. BP network used to identify Chinese characters has
two node outputs. There are 24 output nodes which BP network uses to identify letters, 34 output
nodes to identify combinations of numbers and letters and 10 output nodes to identify numbers.

(3) Sample selection and parameter setting
In this study, we will take 60 images of vehicle license plates captured by cameras as samples, randomly select 30 of them as training samples and take the remaining 60 as the test samples. The original images are changed into character images of the same size after preprocessed. We adopt 20 feature extraction method to process them. Then we select nine different characters for each plate character as training samples. For example, the character A, it means that we select nine different character A from the split photos as training samples of BP network. When parameter is set, we randomly select weights and thresholds of the network. Presume the activation function of the hidden layer is tansig and the output layer activation function is logsig, this experiment error will be set 0.0005, learning rate 0.1, the learning rate increment multiplication factor 1.15, decreasing the learning rate multiplier factor 0.8, and momentum factor 0.9.

(4) The analysis of results
We perform simulations with MATLAB R2013a, number the remaining 60 license plate images from No.1 to No.60, correct the tilt angle of the plate image by Radon after positioning. It is found that only No.2 and No.52 are wrong, and accuracy reaches 96.667%. Therefore it prove that license plate tilt correction algorithm based on Radon transformation can effectively detect the tilt angle of the license plate image and correct it. Meanwhile this algorithm can greatly improve the efficiency and accuracy of the license plate recognition system. In partial vertical projection process, only the two images No.10 and 11 appear errors, which means the accurate rate reaches 97.778%. The main reason why they can’t be recognized is the border. In other words, vertical projection of some borders and characters is too close. However, the method proposed is anyhow effectively improve performance of the license plate recognition system.

Table 2-1 All images identify results

| Images | The original image | Identify Results | Corrective angle |
|--------|--------------------|------------------|------------------|
| 1.JPG  | SUAY6823           | SUAY8823         | -1               |
| 2.JPG  | SUAMK717           | SUAMK717         | -90              |
| 3.JPG  | SUADZ219           | SUA07V19         | 1                |
| 4.JPG  | SUAQ8287           | SUAQ8V87         | 1                |
| 5.JPG  | GUIBB5672          | GUIB85872        | 1                |
| 6.JPG  | SUAW9097           | SUAW9097         | 0                |
| 7.JPG  | SUAMF317           | SUAMF347         | 1                |
| 8.JPG  | SUAAM530           | SUAAM530         | 0                |
| 9.JPG  | GUIAUT263          | GUIAUT466        | -1               |
| 10.JPG | SUAMV889           | SUAMV889         | -2               |
| 11.JPG | SUAEE077           | SUAEE077         | -1               |
| 12.JPG | SUAX8665           | SUAX8665         | 0                |
| 13.JPG | SUEFB319           | SUEFB319         | 0                |
| 14.JPG | SUA3B099           | SUA3B099         | -1               |
| 15.JPG | SUAY6823           | SUAYM823         | 0                |
| 16.JPG | SUAEE077           | SUAEE077         | 1                |
| 17.JPG | GUIA78Q22          | GUIA78Q22        | 2                |
| 18.JPG | SUA05J23           | SUA05J23         | 1                |
| 19.JPG | SUANG577           | SUANG577         | 1                |
From the point of identifying the output, 60 test pictures contains 60 characters, 141 letters and 219 Arabic numerals, totally 420 characters. and the number of recognition errors is 46, including 0 character, 8 letters and 38 Arabic numerals. So the character recognition rate of this algorithm is 100%, letter recognition rate is 94.33%, the Arabic numeral recognition rate is 82.65%, and the average recognition accuracy is 89.05%. We can see that the accuracy is not very high. Since the wrong character errors are 0,1,4,5, Q and S, the reason may be that the border is not entirely cut, resulting in misunderstanding when identifying; some noises still remain after cutting pictures, leading to worse robustness; BP neural network does not set the optimal parameter values. In subsequent experiments, we will make some adjustments for better results.

Figure 2-12 shows the change of the total time from the plate positioning to license plate recognition and the time change of each part. From the results, the total time spent on completing 60 pictures’ identification is 101.998 seconds.

3 Conclusion
Automatic identification technology of license plate, as a part of intelligent transportation, has been more widely used, and is very meaningful for modern traffic. In this paper, we use grayscale, edge detection and a series of morphological operations. Otherwise, we use the improved BP neural network algorithm for license plate recognition, and we also find that with the help of MATLAB, the design of license plate recognition algorithm can effectively realize the license plate recognition.

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