An intelligent control system using an efficient License Plate Location and Recognition Approach

Saeed Rastegar s.rastegar@stu.nit.ac.ir
Faculty of Electrical and Computer Engineering,
Signal Processing Laboratory Babol Noshirvani
University of Technology
Babol, P.O. Box 47135-484, IRAN

Reza Ghaderi r_ghaderi@nit.ac.ir
Faculty of Electrical and Computer Engineering,
Babol Noshirvani University of Technology
Babol, P.O. Box 47135-484, IRAN

Gholamreza Ardeshir g.ardeshir@nit.ac.ir
Faculty of Electrical and Computer Engineering,
Babol Noshirvani University of Technology
Babol, P.O. Box 47135-484, IRAN

Nima Asadi nima228@gmail.com
Faculty of Electrical and Computer Engineering,
Babol Noshirvani University of Technology

Abstract

This paper presents a real-time and robust method for license plate location and recognition. After adjusting the image intensity values, an optimal adaptive threshold is found to detect car edges and then the algorithm uses morphological operators to make candidate regions. Features of each region are to be extracted in order to correctly differentiate the license plate regions from other candidates. It was done by analysis of percentage of Rectangularity of plate. Using color filter makes the algorithm more robust on license plate localization (LPL). The algorithm can efficiently determine and adjust the plate rotation in skewed images. The Binary unit uses Otsu method to find the optimal adaptive threshold corresponding to the intensity of image. To segment the characters of the license plate, a segmentation algorithm based on the profile is proposed. In the following, an optical character recognition (OCR) engine has then been proposed. The OCR engine includes characters dilation, resizing input vector of Artificial Neural Network (ANN). To recognize the characters on the plates, Multi layer Perceptron (MLP) has been used and compared with Hopfield, Linear Vector Quantization (LVQ) and Redial Basis Function (RBF). The results show that MLP outperforms. According to the results, the performance of the proposed system is better even in case of low-quality images or images with illumination effects and noise.

Keywords: license plate recognition (LPR), Rectangularity percentage, optical character recognition (OCR), neural network.

1. INTRODUCTION

Automatic license plate recognition (LPR) has been a practical technique in the past decades [1-6]. One type of intelligent transportation system (ITS) technology is the automatic license plate recognition (ALPR) which can distinguish each car as unique by recognizing the characters of the license plates. In ALPR, a camera captures the vehicle images and a computer processes them and recognizes the information on the license plate by applying various image processing and optical pattern recognition techniques. Prior to the character recognition, the license plates must be separated from the background vehicle images. This task is considered as the most crucial step in the ALPR system, which influences the overall accuracy and processing speed of the whole system significantly. Since there are problems such as poor image quality, image perspective distortion, other disturbance characters or reflection on vehicle surface, and the color similarity between the license plate and the background vehicle body, the license plate is often difficult to be located accurately and efficiently. Researchers have found many diverse methods of license plate localization [7-12]. Edge density and background color have been used to detect a number of plate locations, in (Sherin et al, 2008), according to the characteristics of the number plate .In (Wenjing Jia, 2007), mean shift algorithm and color filter were used. (Rodolfo and Stefano, 2000) devised a method based on vector quantization (VQ). VQ image representation is a quadtree representation using a specific coding mechanism and it gives a system some hints about the contents of the image regions that boost location performance. In (Wang and Lee , 2003), (Bai et al, 2003), (Bai and Liu, 2004) the presence of abundant edges, especially vertical edges, in license plate regions is due to the presence of characters used to generate the candidate regions for classification. Combined with geometrical properties of license plates, good performance is obtained by the algorithms even dealing with some deficient license plates (Bai and Liu, 2004). Other popular methods focus on detecting the frames, e.g. the Hough Transform which is used widely in (Yanamura et al, 2003). In addition to the algorithms based on gray-level image processing, color information of license plates also plays an important role in license plates localization, where the unique color or color combination between the license plates and vehicle bodies are considered as the key feature to locate the license plates. In order to determine the exact color at a certain pixel, neural network classifier (Wei et al, 2001; Kim et al, 2002) and genetic algorithm (Kim et al, 1996) are widely used. License plates (LP) are identified as image areas with high intensity rather thin than dark lines or curves. Therefore, the location is handled by looking for rectangular regions in the image containing maxima of response to these line filters, which is computed by a cumulative function (Luis, Jose, Enrique, Narucuso, & Narucuso, 1999). Plate characters can be directly identified by scanning through the input image and looking for portions of the image that were not linked to other parts of it. If a number of characters are found to be in a straight line, they may make up a license plate (Lim, Yeo, Tan, & Teo, 1998). Fuzzy logic has been applied to solve the problem of locating license plates by (Zimic, Ficzko, Mraz, and Virant, 1997). The authors made some intuitive rules to describe the license plate, and gave some membership functions for the fuzzy sets ‘‘bright’’ and ‘‘dark’’,and ‘‘bright and dark sequence’’ to get the horizontal and vertical plate positions. However, this method is sensitive to license plate color and brightness and needs much processing time. Using color features to locate license plate has been studied by (Zhu, Hou, and Jia 2002) & (Wei, Wang, and Huang, 2001), but these methods are not robust enough to the different environments. We propose a new approach using an automated license plate location and recognition that overcomes most of the problems with previous approaches. The mechanism is able to deal with difficulties raised from illumination variance, noise distortion,and complex and dirty backgrounds. Numerous captured images including various types of vehicles with different lighting and noise effects have been handled. The remainder of the paper is organized as follows. Section 2 presents the proposed model and describes the procedures of the system. Section 3 describes the learning and recognition processes. Section 4 explains the experimental settings, and the experimental results on different testing sets will be reported in this section. In section 4, also the architecture parameters will be described. Finally, a conclusion and discussion are presented in Section 5.

2. THE PROPOSED ALGHORITHM

According to the feature characteristics of car license plates, we considered that the license plates are rectangular with blue regions in left containing eight alphanumeric formats. Fig. 1 shows an example of different located license plates. Our intelligent access control system based on license plate recognition can be broken down into the following block diagram, as illustrated in Fig. 2. Alternatively, this progression could be viewed as the reduction or suppression of unwanted information from the information carrying signal. Here is a video sequence containing vast amounts of irrelevant information, to abstract symbols in the form of the characters of a license plate.

FIGURE 1: Examples of different located license plates.

2.1. Captured RGB image

Experiments have been carried out using a camera to capture the approaching vehicle image. Various vehicle images with different camera positions and different orientations have been processed. Current Iranian cars have license plates with a white background and a blue region at the left. Each car is specified by eight characters, seven digits and one Persian alphabet. Images have been taken by "canon powershot A520".$(640 * 460 \ by \ pixels)$.

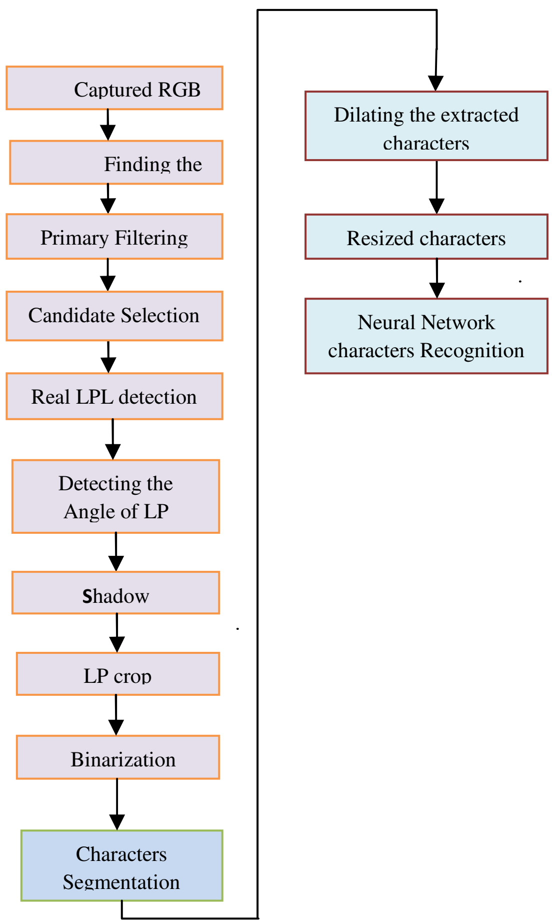
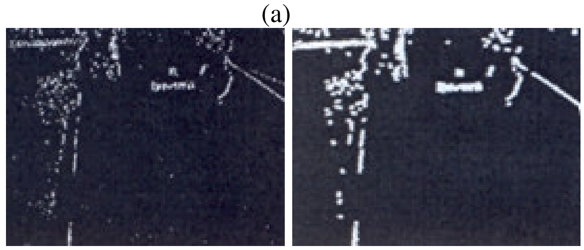


FIGURE 2: Block diagram of the proposed framework.

2.2. Finding the contours

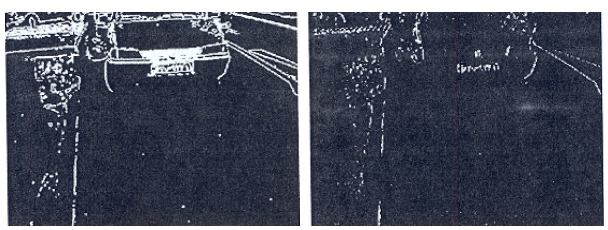
In the algorithm, gradient operators [13-14] have been used to detect edges of grey level images which form primary regions. Then a morphological operator is used to dilate adjacent regions. Fig.3 shows the output of this step of the algorithm. Images of cars were taken from different distances. The distance is the important parameter in the proposed algorithm. In some instances, due to adhesion of the plate to the body of the car, Sobel operators cannot detect the plate region. The problem of adhesion can be removed according to different distances of car from the camera; a suitable edge detector is used. This unit uses sobel operator has been used for distances less than 3.5 meters, and For distances longer than 3.5 meters a structure element [-1 0 1] has been applied to the image.Fig.4.describes the explained problem and how the proposed method solves it.

(a)



(b) (c)

FIGURE 3: (a) grey image, (b) binary image after edge detections and (c) dilation using morphological operator.



(a) (b)

FIGURE 4: (a) adhesion of car plate to other excessive parts of the car and (b) applying proposed method to solve the problem.

2.3. Primary filtering

Selection of candidate regions has been done based on two criteria. This is the reason why the speed of computation increases the speed of computation. The regions with sizes smaller or bigger than (the) threshold and region in which the aspect ratio is smaller than 5, are removed at this step. Note that the efficient cluster-Otsu method is used to make binary images. Fig.5. illustrates the operation of finding candidate regions on the image which resulted in previous step.

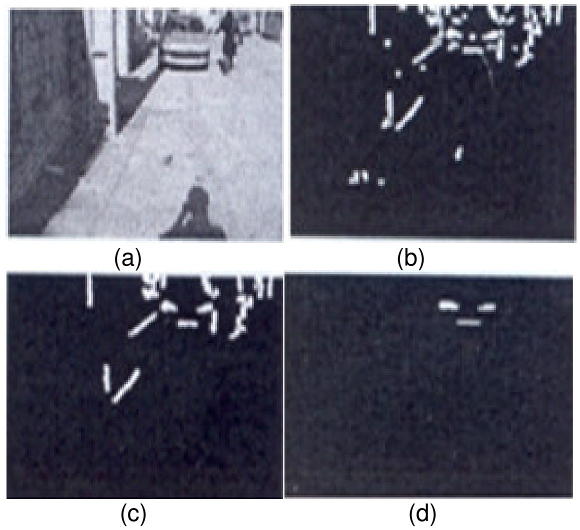


FIGURE 5: (a) primary image, (b) regions with vertical edges, (c) removed regions, less than the threshold and (d) removed additional regions, by applying two terms.

2.4. Candidate regions

Extracted regions after primary filtering are considered as candidate regions.

2.5. Real LPL detection

In this unit real license plate localization is determined among candidate regions. It includes two stages. In the first stage rectangularity percentage of the candidate regions is attained and the color filter is used to the rest of the candidate regions as a second stage.

2.5.1 Rectangularity percentage

In this section four criteria have been used to determine the rectangularity percentage. The first criterion is the ‘aspect ratio’ of width to height: for a real license plate, this Value is five. However, when we have a pan or tilt condition for the plate this value is less than five. The ‘Perimeter ratio’ is used as the second criterion. For a rectangle, the parameter ratio is one. It is a good criterion to estimate the percentage of rectangularity on candidate regions. The third criterion is ‘Extend’. Each shape with a completely filled box, can be used as a suitable feature for calculating the percentage of rectangularity. Finally, the fourth criterion is Solidity. Rectangular is the smallest convex polygon that can surround objects. Oghlidian distances from ideal values of these criteria are calculated at each step and then normalized by Gaussian filter. Fig.6. describes the explained procedure. The result of this stage is shown in Fig.7.

2.5.2. Color filter

Color is another feature which is used in the LP system. There are many color models which can be used in LPL unit. It's clear that, color model type varies according to the characteristics of car LP in each country. For instance, yellow background is used in Italian or Egyptian LP. Current Iranian car plates have a blue region in the left. So, finding a color space which is sensitive to blue color is important. After many tests on different LP conditions are done YCbCr model is applied in the second stages of the LPL unit.

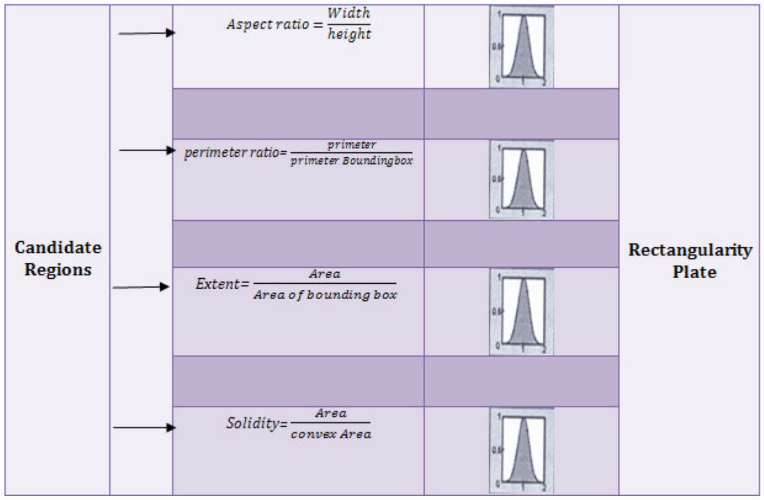
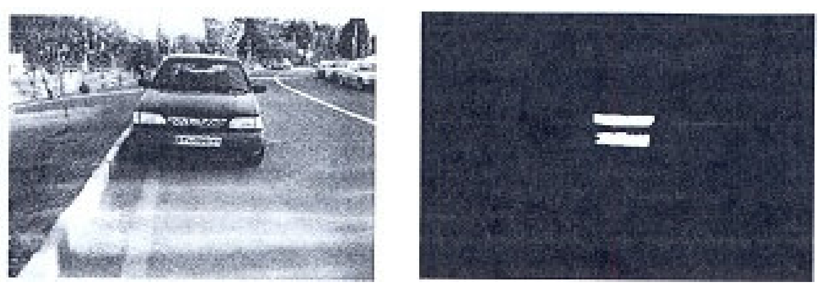


FIGURE 6: First stage of the license plate localization (LPL) unit.



(a) (b)

FIGURE 7: (a) input image and (b) output of the first stage of LPL unit.

2.5.2.1 YCbCr space

The CIEYCbCr is a scaled and an offset version of the YUV color space. The YUV color space is the basic color space used by the composite color video standards. The YUV signal separates the intensity Y from the color components UV that correspond to the hue and saturation aspects of the model. Therefore the UV components, also called chrominance, are usually subsampled in image applications. The YUV parameters in terms of RGB are:

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ 0.299 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{pmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

the YCbCr results from YUV as following

$$Y = 0.299R + 0.587G + 0.114B \quad (2)$$

$$Cb = B - Y \quad (3)$$

$$Cr = R - Y$$

2.5.2.2 Blue color filter

In this work, Gaussian filter has been used to detect blue region in the LP. Before applying Gaussian filter to Cr and Cb components of the image, YCbCr model has been applied. Statistical methods are used to determine the variance and average parameters needed in Gaussian filter. Also, color components are obtained by testing thirty car images in different conditions. For Gaussian filter we have:

$$f(x, y) = exp[\frac{-1}{2}(X - m) C_x^{-1} (X - m)^T] \quad (4)$$

$$m = [\overline{C_b} \quad \overline{C_r}]$$

Where X is the color components vector in Cartesian that coordinates with the input image. μ, is the average vector and C_x , is covariance matrix. Fig.8. shows the results of applying the color filter to the image.

(a)

(b)

FIGURE 8: (a) input grey image and (b) extraction of the blue region from the RGB image by applying the color filter.

Using the blue color filter on two detected regions on the plate region in figure 8(b), the real plate is detected.

2.6. Detecting the angle of LP

One of the problems confronted in LP images is rotation of images which makes recognition of characters on the plate difficult. To estimate the rotation angle, moment of region scan be used. Degree of rotation is considered respected to camera diaphragm as:

$$\alpha = \frac{1}{2}.\tan^{-1}[\frac{2m_{1.1}}{m_{2.0} - m_{0.2}}] \quad (5)$$

$$\mu_{i,j} = \sum_{x=1}^{H} \sum_{y=1}^{W} (x-\overline{x})^i (y-\overline{y})^j \quad (6)$$

Where $\mu_{i,j}$, is (i, j)th moment in x, y axes, α is the rotation value respected to x axis, H is the height of plate and W is the width of LP(it).After finding the angle, rotation adjustment will be done. New position assigned to each pixel is:

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} cosa & -sina \\ sina & cosa \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} \qquad (7)$$

Fig.9. shows the image frame before and after the rotation adjustment.

(a) (b)

FIGURE 9: (a) the image before rotation and (b) rotated image after rotation adjustment.

2.7. Shadow removal

The Shadow in images can be divided into regular and irregular. In the irregular shadow, LP is exposed to different illustrations. Frequency components are the main keys for the detection of the shadow. Frequency components of characters are much more than shadow components. Bothat morphology transform has been used to smooth the image. Its Structure element (SE) is a square element with length of $K=0.25H$ in which H is the height of LP.

2.8. License plate crop

The proposed approach is based on the vertical gradient operation. By applying $[-1\,1\,0]$ operator, gradient amplitude is obtained for each grey pixel. Profile of the image, $f(x, y)$, is:

$$projection(x) = E_R = \sum_{y=1}^{W} \left| \frac{\delta f(x, y)}{\delta x} \right| \qquad (8)$$

Where y shows the column of grey image and W is the width of LP. For an image with $W \times H$ size, $H \times 1$ is assigned to E_R.

Excess part of the LP is removed by applying a threshold value about maximum value of E_R .an efficient crop is done by using the following equation:

$$R_{\max} = \arg Max\{E_R\} \qquad (9)$$

$$\Rightarrow \{R_{high} = \{R \,|E_R = 0.2E_{\max}, R = 1 \rightarrow R_{\max}$$

$$\Rightarrow \{R_{bottom} = \{R \,|E_R = 0.2E_{\max}, R = R_{\max} \rightarrow H$$

Where $E_{\max}$ and $R_{\max}$ are the maximum energy and related line respectively. R_{high} Is the highest line and R_{bottom} is the lowest line to be cropped.

2.9. Binary unit

Before character segmentation, plate characters are converted to binary code. To convert the image, a threshold value is determined by using efficient cluster-Otsu method [20].

2. 10. Characters Segmentation

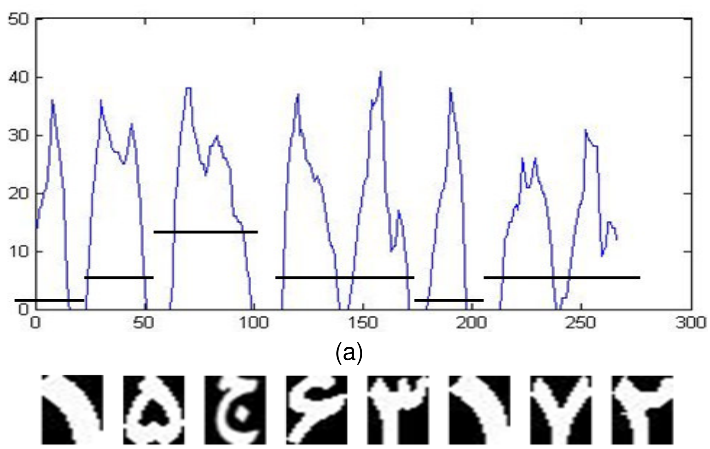
To segment characters, vertical projection is obtained by summation of columnar pixels which is defined by:

$$P_y(y) = \sum_y \mathrm{Im}age(x, y) \quad (10)$$

The psuedocode shown in Fig. 10 explains the method used to segment characters of the license plates [2]. Fig. 11 shows the results of the character segmentation.

```
 For every column sum the pixels {
If (sum = 0) consider that a separating line;
}
Get the area between the separating lines;
Take the largest 8 areas to be the segments for the 8 characters;
```

FIGURE 10: Pseudocode for character segmentation



(a)

(b)

FIGURE 11: (a) vertical profile and (b) characters segmentation.

2.11. Dilating the character image

In this step of algorithm, a dilation operation is applied to the resultant segmented characters to enhance the image.

2.12. Resized characters

Before applying the neural networks, the characters are re-sized to ' $20 * 30$ '.

3. NEURAL NETWORK AND LEARNING DATASET

Twenty different images for each character were taken and used for constructing a learning dataset, which all had a standard size. Aspect Ratio of zero pixels to whole pixels, Top-down projection and/or left right projection could have been used to extract the feature vector for each character and so. However, for the sake of simplicity, in this work the feature vector for each character was obtained by summing the Pixels in each row and column. The ANN unit in this work uses MLP network after testing different networks (Table1).

4. EXPRIMENTAL RESULTS

To show the efficiency of the proposed system, experiments have been done on numerous captured images including various types of vehicles with different lighting and noise effects. Also, experiments have been carried out using different camera positions and different orientations. To validate the results, each experiment is repeated 5 times and the result is reported as an average over these 5 repetitions. Moreover, in this section we compare the performance of the proposed method with some other methods: line sensitive filters (Luis et al., 1999), row-wise and column-wise DFTs (Parii, Claudio, Lucarelli, & Orlandi, 1998), and edge image improvement (Ming et al., 1996 & Zheng et al., Zheng, Zhao, & Wang, 2005), and fuzzy logic approach (Zimic et al., 1997) Works well under the assumptions that the Majority of plates are white and black characters, while most of the Italian license plates are yellow with black characters. Therefore, these three methods are not employed in our comparative experiments. The method proposed in Zheng et al. (2005) has some drawbacks. It has much computational time; some characters in this method are relative to the estimated size of the license plate. So, the method works well in case of that the license plates in images have the same size. Besides, no handling of rotational adjustment is considered. The ‘‘line sensitive filters’’ method consists of three steps’’ subsampling image, applying line sensitive filters, and looking for rectangular regions containing maxima of response. The ‘‘row-wise and column-wise DFTs’’ method involves four steps: decomposing expected harmonics by using horizontal DFT on the image, averaging the harmonics in the spatial frequency domain, finding the horizontal strip of the image containing the plate by maximizing the energy, and finding the Vertical position of the plate in the same way by using vertical DFT on the candidate strips. ‘‘The edge image improvement’’ method contains five steps: extracting the edge image using Sobel operators, computing the horizontal projections of the edge image, calculating the medium range of the edge density level, eliminating the highest and lowest portion of the horizontal projections to simplify the whole image, and finding the candidates of the license plates.
Two sets of vehicle images are used in our experiments. The first set has 170 images and they are captured on gates at different camera positions and orientations. The second set has 150 images, which are captured in the shadow of strong sunlight near a road, lighting effects, plate damage, dirties and complex backgrounds. The dataset used in the experiments consists of 340 characters. 205 characters were used for training and 135 characters for test. Table 1 shows the results of four neural networks on this dataset. According to these results, MLP network has been chosen due to its better performance. Precision Correct in table 1 is obtained by using the following equation:

$$Percent\ \ Correct = [test\ sample - \left(abs \left(\frac{A - LL}{2} \right) \right)] * 100 \qquad (11)$$

Where A is the output of the network resulted from simulation and LL is the real value of output. All the mentioned methods have been applied to the two sets and the results have been shown in Table 2. From this table, it can be seen that the proposed method outperforms the other four methods. The high location rates on the three sets reveals robustness and efficiency of the proposed method. For the other methods, most misallocated plates happened with images containing noise effects, rotations, and low-resolutions, and the images captured in string sunlight or under the gloomy light condition.

Number	Networks	Percent Correct (%)	Training Times
1	LVQ	76	24.4
2	Hopfield	83	30.4
3	RBF	97.6	27.4
4	MLP	99.2	28.18

Table 1: a Comparison on the efficiency of different networks in LP recognition:

The average processing time for the 5 stages of the license plate location in the proposed method has been shown in Table 3. Most of the elapsed time used is for the license plate extraction and rotation adjustment. The computational time needed by the five methods has been shown in Table 4, when they run on Pentium-four 2.4 GHz, 512 MB RAM PC.

Number	Methods	Datasets	Plates not Detected	Location rates (%)
1	Line sensitive filters , Luis et al. (1999)	Dataset1 Dataset2	10 14	94.2 91.1
2	Row-wise and column -Wise DFTs, Parii et al. (1998)	Dataset1 Dataset2	8 11	5.7 92.6
3	Edge image improvement Ming et al. (1996)	Dataset1 Dataset	7 8	96.2 94.6
4	Zheng et al. method, Zheng et al. (2005)	Dataset1 Dataset	5 8	97.1 95.2
5	The proposed method	Dataset Dataset	0 1	100 99.4

Table 2: Comparison of location rates of the five methods on two sets:

License plate Extraction	skew angle and rotation adjustment	Crop LP	shadow attenuation	LP-character segmentation	OCR	total time
0.93	1.13	0.12	0.1	0.28	0.14	2.7

Table 3: The processing time for each stage of the proposed method (s)

number	Method	Time(s)
1	Line sensitive Filters DFTs	2.1
2	Row-wise and column-wise	2.44
3	Edge image Improvement	1.97
4	Zheng et al. method	5.04
5	The Proposed method	2.3

Table 4: Comparison of LP location computational time of the five methods(s)

5. CONCLUSION

In this paper, we have proposed an intelligent vehicle-access control system based on an efficient license plate location and recognition approach. The multilayer perceptron neural network (MLPNN) is selected as a powerful tool to perform the recognition process. The proposed system is successfully implemented in experimental settings that are representative for of many practical simulations. The experimental results demonstrate that the proposed technique is capable of locating a CAR LICENSE PLATE to infer the position of a part of interest effectively. It has been shown that the system is able to handle images at low-resolutions and images containing noise. Furthermore, experimental results have proved that the proposed system is able to locate and recognize LABELS even in damaged patterns. A study of the different parameters of the training and recognition phases showed that the proposed system reaches promising results in most cases and can achieve high success rates. A great effect of our method in license plate location has been confirmed by the experiments.

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