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An Efficient Method for Vehicle License Plate Detection in Complex Scenes

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Abstract

In this paper, we propose an efficient method for license plate localization in the images with various situations and complex background. At the first, in order to reduce problems such as low quality and low contrast in the vehicle images, image contrast is enhanced by the two different methods and the best for following is selected. At the second part, vertical edges of the enhanced image are extracted by sobel mask. Then the most of the noise and background edges are removed by an effective algorithm. The output of this stage is given to a morphological filtering to extract the candidate regions and finally we use several geometrical features such as area of the regions, aspect ratio and edge density to eliminate the non-plate regions and segment the plate from the input car image. This method is performed on some real images that have been captured at the different imaging conditions. The appropriate experimental results show that our proposed method is nearly independent to environmental conditions such as lightening, camera angles and camera distance from the automobile, and license plate rotation.

Keywords: License Plate Detection, Image Enhancement, Background and Noise Removing, Morphological Operations

1. Introduction

With the rapid development of highway and the wide use of vehicle, researchers start to pay more attention on efficient and accurate intelligent transportation systems (ITS). It is widely used for detecting car's speed, security control in restricted areas, highway surveillance and electric toll collection [1]. Vehicle license plate (VLP) recognition is one of the most important requirements of an ITS. Although any ITS and specifically any VLP recognition contains two part in general, license plate detection and recognition, detecting and segmenting VLP correctly is most important because of existing conditions such as poor illumination, vehicle motion, viewpoint and distance changes. The problem of automatic VLP recognition has been studied since 1990s. The first approach was based on characteristics of boundaries [2,3]. In this method, an image was binarized and then processed by certain algorithms, such as Hough transform, to detect lines. In general, the most common approaches for VLP detection include texture [1,4], color feature [5], edge extraction [6], combining edge and color

[7], morphological operation [5,8] and learning-based method [9]. Using color feature is benefit when lightening is unchanged and stable. However methods based on edge and texture are nearly invariant to different illumination and so they are widely used for VLP detection. These methods use the fact that there are many characters in the license plate, so the area contains rich edge and texture information. Zhang *et al.* [9] proposed learning-based method using AdaBoost for VLP detection. They used both global (statistical) and local (Haar-like) features to detect the license plate.

In this paper, we do pre processing for image enhancement at first. The some regions are candidate as a license plate during three procedures. Finally considering geometrical features, the license plate is segmented nearly independent of image capturing conditions.

This paper is organized as follows: in Section 2, different styles of Iranian license plates are illustrated in Section 3. We express how our image bank is provided. In Section 4, the proposed algorithm is described and in Section 5 the experimental results are reported. Finally, in Section 6 we have conclusion.

2. Iranian Vehicle License Plate

We have considered 3 classes for Iranian VLP, they are private, public (such as taxi, truck and bus) and governmental vehicles. Each class has own plate and character color. In addition, though Farsi characters are 32, only some characters are used for VLP. Color arrangement, characters and outline of the Iranian VLP are shown in **Table 1**.

3. Provided Image Bank

As respects, the aim of this paper is detecting the Iranian license plates in images with complex scenes. Due to the unavailability of required images, in several stages by using 2 digital cameras and mobile cameras, we have provided 350 images under various illumination (lightening), different distances and angles of stationary and moving vehicles. After providing images, in order to increase the processing speed and facilitate the license plate detection, input color image is converted to grayscale image. The size of images is 640×480 pixels.

4. Efficient License Plate Detection

Our proposed method is composed of several parts, **Figure 1** shows the flowchart.

4.1. Pre Processing

Low contrast may have the most important effect on failing a license plate detection algorithm. Severe lightening conditions, changing plate orientation and various distances are main reasons for having low contrast and quality in the car images. Therefore, contrast enhancement seems to be necessary, specially at locations where might be a license plate. So, in following we improve different images using two methods, they are intensity variance [6] and edge density [7], and choose the best for pre processing images.

4.1.1. Intensity Variance

Zheng *et al*. [6] used the local variance of pixel intensities to improve image contrast at regions that may be plate. They proposed an enhancement function which increases image contrast at regions that local variance of intensity is around 20. The enhancement function was suggested as follows:

$$I'_{ij} = f\left(\sigma_{w_{ij}}\right)\left(I_{ij} - \overline{I}_{w_{ij}}\right) + \overline{I}_{w_{ij}} \tag{1}$$

where I_{ij}, and I'_{ij} denote the intensities of the pixel in the input grayscale image and enhanced image, and w_{ij} is a window centered on pixels of grayscale image. $\overline{I}_{w_{ij}}$, and $\sigma_{w_{ij}}$ are average luminance and standard deviation respectively. The enhanced coefficient is defined as follows:

$$f(\sigma_{w_{ij}}) = \begin{cases} \dfrac{3}{\dfrac{2}{400}\left(\sigma_{w_{ij}} - 20\right)^2 + 1} & \text{if } 0 \le \sigma_{w_{ij}} < 20 \\ \dfrac{3}{\dfrac{2}{1600}\left(\sigma_{w_{ij}} - 20\right)^2 + 1} & \text{if } 20 \le \sigma_{w_{ij}} < 60 \\ 1 & \text{if } \sigma_{w_{ij}} \ge 60 \end{cases} \tag{2}$$

With respect to **Figure 2**, the intensities of pixels in the input grayscale images with local variance between 0 and 60 are enhanced.

Figure 3 shows the result of image enhancement using the zheng's method.

4.1.2. Edge Density

Abolghasemi *et al.* [7] used the density of vertical edges (instead of the variance of intensity) as criterion for local enhancement of car image. License plate of the car consist of several characters (8 characters for Iranian VLP), so the license plate area contains rich edge information. We can employ the edge information to find the location of plate in an image. At first, they [7] used the vertical sobel mask and obtained the gradient image:

Table 1. Different styles of Iranian VLP.

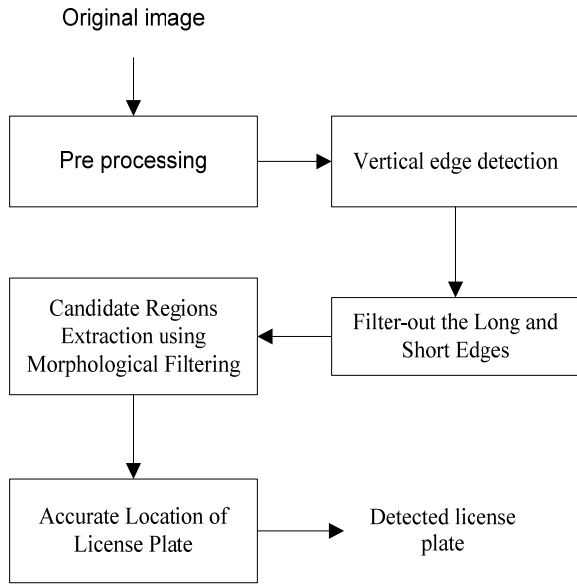| Vehicle Type	Plate Color	Character Color	Outline of VLP
Private (automobile)	white	black	
Public (taxi, truck and bus)	yellow	black	
Governmental	red	white	

Figure 1. Flowchart of our proposed system for VLP detection.
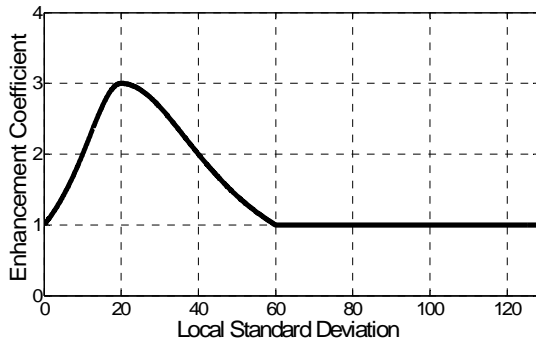

Figure 2. The graph of enhancement coefficient, $f(\sigma_{w_{ij}})$, based on the local standard deviation, $\sigma_{w_{ij}}$.
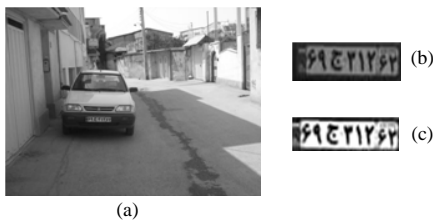

Figure 3. (a) input grayscale image. Iranian license plate before (b) and after (c) enhancement using intensity variance method.

$$h = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{3}$$

Then, they compared pixel values with a predefined threshold and the vertical edge image has been achieved.

In the next step, the vertical edge image is convolved with the 2-D Gaussian kernel and estimation of the edge density is yielded. The results on a sample image are shown in **Figure 4**.

In order to enhance the input image with respect to the estimations of edge density, an enhancement coefficient is suggested as follows:

$$I'_{ij} = f\left(\rho_{w_{ij}}\right)\left(I_{ij} - \overline{I}_{w_{ij}}\right) + \overline{I}_{w_{ij}} \tag{4}$$

where I_{ij}, I'_{ij} and $\overline{I}_{w_{ij}}$ are explained in the previous step. $f\left(\rho_{w_{ij}}\right)$ is the weighting function, regarding the estimation of edge density. This function is sketched in **Figure 5**.

As can be seen in **Figure 5**, the intensity of pixels with the edge density among 0.15 to 0.45 is to be enhanced. The enhancement coefficient $f\left(\rho_{w_{ij}}\right)$ is defined as follows:

$$f\left(\rho_{w_{ij}}\right)$$
$$= \begin{cases} \dfrac{3}{\dfrac{2}{0.15^2}\left(\rho_{w_{ij}} - 0.15\right)^2 + 1}, & \text{if } 0 \le \rho_{w_{ij}} < 0.15 \\[3em] \dfrac{3}{\dfrac{2}{\left(0.5 - 0.15\right)^2}\left(\rho_{w_{ij}} - 0.15\right)^2 + 1}, & \text{if } 0.15 \le \sigma_{w_{ij}} < 0.5 \\[2em] 1, & \text{if } \rho_{w_{ij}} \ge 0.5 \end{cases} \tag{5}$$

Figure 6 shows the result of enhancement by this method.

Even though for normal images, as it can be seen in **Figure 7(a)**, both intensity variance [6] and edge density [7] can improve the VLP, when the distance and angle
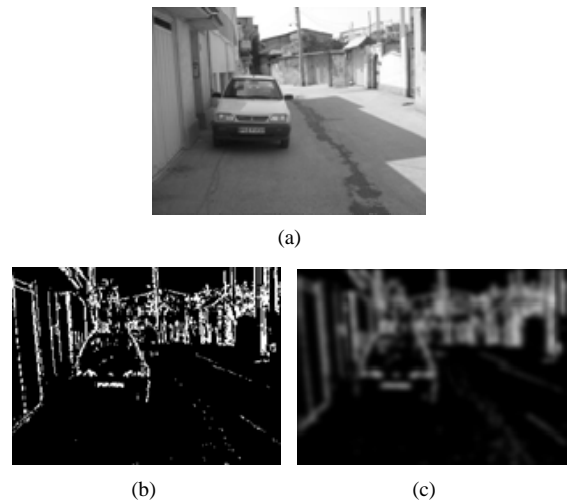

Figure 4. (a) Input grayscale image, (b) vertical edge image and (c) the edge-density estimation image.
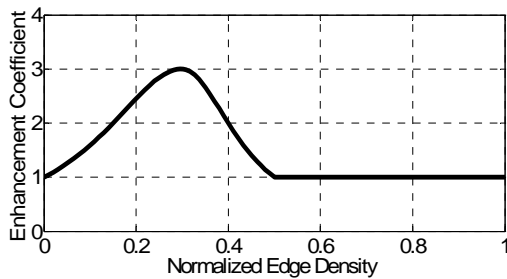
Figure 5. The graph of enhancement coefficient, $f\left(\rho_{w_{ij}}\right)$, based on normalized edge density, $\rho_{w_{ij}}$.
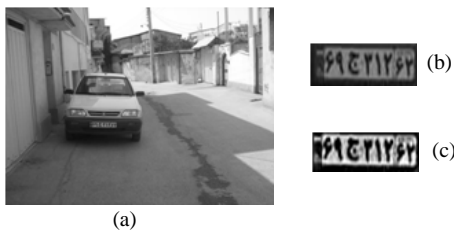

Figure 6. (a) input grayscale image. Iranian license plate before (b) and after (c) enhancement using edge density method.
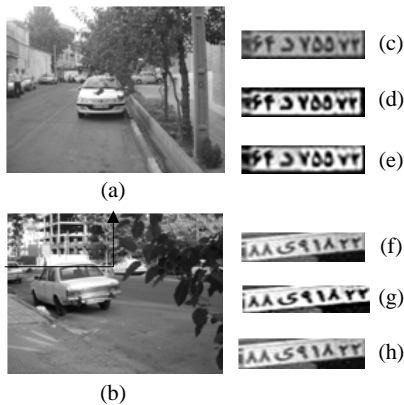

Figure 7. (a),(b) input grayscale image. Iranian license plate (c),(f) without enhancement (d),(g) improved using edge density method (e), (h) improved using intensity variance method.

between camera and vehicle are increased, zheng's method fails while abolghasemi's method already improves the quality of VLP considerably, **Figure 7(b)**. so, in this work we employ edge density method for pre processing.

4.2. Detecting the VLP

After enhancing an input image by using suitable method (edge density), we should detect any existed license plate in the improved image. We do the following stages for this purpose.

4.2.1. Vertical Edge Detection

Edge detection is one of the most important processes in image analysis. An edge represents the boundary of an object which can be used to identify the shapes and area of the particular object. When there is contrast difference between the object and the background, after applying edge detection, the object edges will be illustrated. We select the vertical sobel operator, Equation (3), to detect the vertical edges.

After convolving the enhanced car image with the vertical sobel operator, an estimation of vertical gradient image is yielded. Finally, we get a binary image, as shown in **Figure 8(a)**, by using a threshold value.

4.2.2. Filter-Out the Long and Short Edges

After extracting vertical edges from the enhanced image, using morphological filtering obtains candidate regions those may be a license plate. But, as it can be seen in **Figure 8(a)**, there are many long background and short noise edges that may interference in the morphological filtering process. In order to resolve this problem, an effective algorithm is used to remove the background and noise edges [6]. The filter-out image after removing unwanted edges is shown in the **Figure 8(b)**.

4.2.3. Candidate Regions Extraction Using Morphological Filtering

Morphological filtering is used as a tool for extracting image components and so representing and describing region shapes such as boundaries. In this part, we use a morphological operation for extracting candidate regions. Hence, we implement the morphological closing and opening that defined as follows:

Closing operation $\quad I \bullet S_{m \times n} = (I \oplus S_{m \times n}) \Theta S_{m \times n}$

Opening operation $\quad I \circ S_{m \times n} = (I \Theta S_{m \times n}) \oplus S_{m \times n}$

where $\oplus$, and Θ denote dilation and erosion operations, respectively. $S_{m \times n}$ denote a structuring element with size $m \times n$, all entries in $S_{m \times n}$ are one. The output of this stage is shown in **Figure 9(a)**.

4.2.4. Accurate Location of License Plate

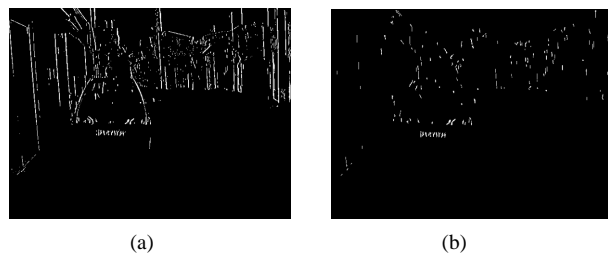After using morphological filtering, still many regions

Figure 8. (a) vertical edge image, (b) removing background and noise edges (filter-out the long and short edges).
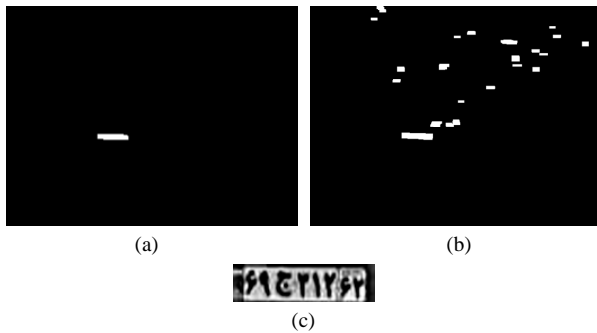
(a)   (b)

(c)

Figure 9. (a) Connected regions obtained from morphological process, (b) after applying features (c) cropped image.

are candidating as a license plate. So we consider some features such as area, aspect ratio (height per width) and edge density in order to discard wrong candidate regions. Values for these features are set experimentally based on our test images. These features are scale-, luminance- and rotation-variant. Progressive of using these features to remove non-plate candidate regions can be seen in **Figure 9(b)**.

5. Experimental Results

We have run our proposed algorithm on laptop Core 2 Due CPU 2.26 MHz with 2 GB of RAM under MATLAB R2008b environment. In Section 3, we described how the vehicle images are provided. Some sample images of our database are shown in **Figure 10**.

Now, in order to evaluate the accuracy of our proposed method, we categorize the provided database into three categories including: Angle (high angle (>30 degree & <60 degree) and low angle (<30 degree)), Distance (short distance (<4 m) and normal distance (>4 m & <12 m) and low quality or contrast (evening, sunlight,
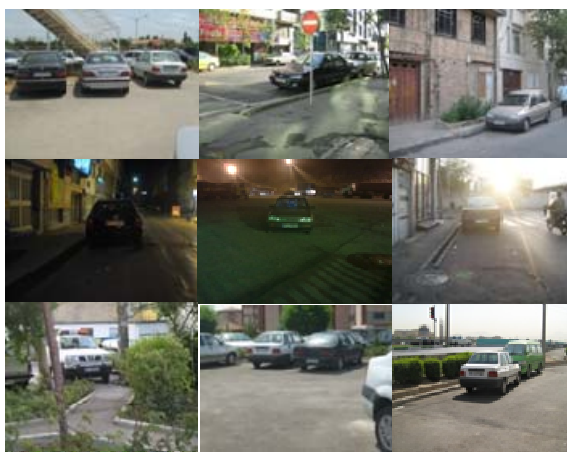

Figure 10. Some sample images of our database.

and rainy or cloudy weather).

Table 2 shows the accuracy of the proposed algorithm under mentioned conditions.

As it is written in **Table 2**, the average accuracy achieved by our proposed method for license plate detection is 95.2%. It means that we could detect 333 Iranian license plate correctly. Although our achieved accuracy is less than what zheng [6] got but we believe our provided image bank is more complex. Because of showing in **Figure 7**, the zheng's method is sensitive to real situations such as existing long distance and high angle. **Table 3** shows the result of license plate detection for several vehicle images in our categories.

Table 2. Accuracy achieved by our proposed method.

Images in Different Situations		Number of Images	Accuracy (%)
Distance	short	100	97
	normal	100	95
Angle	low	50	98
	high	50	94
Low Quality		50	92
Average (350 Images)			95.2

Table 3. Detected license plate by our proposed algorithm.

Input Gray Scale Image	Detected License Plate	Different Situations
		short distance
		normal distance
		low angle
		high angle
		low quality (sunlight)

6. Conclusions

In this paper, an efficient license plate detection method is proposed which performed on images with complex scenes. We used edge density as pre processing for image enhancement. Then by using vertical sobel mask, removing background and noise edges, and employing morphological filter, some regions are candidate as license plate. Finally considering geometrical features (such as area of the regions, aspect ratio and edge density), the license plate from the input car image is extracted. Although the proposed algorithm performs on the Iranian vehicle license plates under various situations such as different lightening conditions, varied distances and existence angle between the camera and the vehicle and varied weather conditions, we believe its performance is yet appropriate if we try to detect the foreign license plate.

7. References

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