# Farsi License Plate Detection and Recognition Based on Characters Features

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**ABSTRACT:**
In this paper a license plate detection and recognition system for Iranian private cars is implemented. The proposed license plate localization algorithm is based on region elements analysis which works properly independent of distance (how far a vehicle is), rotation (angle between camera and vehicle), and contrast (being dirty, reflected, or deformed). In addition, more than one car may exist in the image. The proposed method extracts edges and then determines the candidate regions by applying window movement. The region elements analysis includes binarization, character analysis, character continuity analysis and character parallelism analysis. After detecting license plates, we estimate the rotation angle and try to compensate it. In order to identify a detected plate, every character should be recognized. For this purpose, we present 25 features and use them as the input to an artificial neural network classifier. The experimental results show that our proposed method achieves appropriate performance for both detection and recognition of the Iranian license plates.

**KEYWORDS:** License plate detection, Characters recognition, Region elements analysis.

## 1. INTRODUCTION

An intelligent transportation system is an important tool for analyzing and controlling the moving vehicles in cities and freeways. License plate recognition (LPR) is a necessary tool for any intelligent transportation system, generally. Usually, LPR systems consist of three main parts: license plate detection, character segmentation, and character recognition. License plate detection is the most important and difficult stage. During recent years, several methods have been employed for detecting license plates. For this purpose, [1] used color processing where the unique color or color combination between the license plate and vehicle body, or between the plate background and text color was considered as the key feature to detect the license plate location, [2]- [4] used edge analysis and [5]– [6] used neural networks and other classifiers. Anyway, most of the existing methods fail in real scenario or strongly depending on input images. In this paper, we have considered the content plate characteristics and present a reliable algorithm to detect multiple license plates under various photographs and different conditions.

There are numerous algorithms for character recognition such as: statistical classifiers, computational intelligence architectures, and pattern matching techniques. Although there are various types of classifiers for recognizing license plate's characters, artificial neural network (ANN) is a well-known classifier. ANN needs the value features as input. In this paper, we suggest 25 features and use multilayer perceptron ANN to recognize the license plate characters.

The paper is organized as follows: our proposed method for Iranian license plate detection and recognition are explained in section 2 and section 3 and we draw some conclusions in section 4.

## 2. DETECTING THE IRANIAN LICENSE PLATE

In this section, we try to detect the Iranian license plates in complex scenes. The procedure of our proposed method includes vertical edge detector, obtaining candidate regions and analyzing region elements. After localizing plates the existed angles between cars and camera are also compensated.

### 2.1. Vertical Edge Detector

Edge detection is one of the most important parts in image processing. An edge map has greatly reduced complexity and retained the important information in the image. It seems that, the density of vertical edges is more than horizontal edges for the most characters of

any Iranian license plates such as others [2]-[4]. Although there are many edge detectors, we have used the vertical Sobel mask for this purpose because of being quick to implement and no complex. In Fig. 1 and Fig. 2, the four different pose original images and their extracted vertical edges are shown.

### 2.2. Obtaining Candidate Regions

After extracting the vertical edges, it turns to mark candidate regions. These regions are determined via two steps. They are moving windows and checking the aspect ratio feature.

Moving windows means that first, we select the smallest window size which can be considered as a license plate and scan the image. Then, the size of the window is increased, and the image is scanned again. The window movement procedure is continuing until the size of the window is the same as the image. During every window movement, the considered property for candidate the license plate is controlled, and the contents of a window that could not satisfy the proposed merit would be removed, or discarded. We apply edge density to determine whether a license plate presents in a window, it is obtained as:

$$\text{edge}-\text{density}=\frac{\sum_{i=1}^{x}\sum_{j=1}^{y}|ed(i,j)|}{x\times y} \quad (1)$$

where x and y are window size, and $ed(i,j)$ is edge value, which is obtained in section 2.1. The windows that their edge densities are greater than the predefined threshold are selected as the license plate probable region and the remaining areas are removed. About, 40% of Iranian license plate's area is empty and 60% is characters area. Then, we have chosen the threshold value equals to 55. Fig. 3, shows the window movement output images.

We know the aspect ratio (length to width) of any Iranian standard license plate is equal to 5. Anyway, it changes whenever there is the angle between camera and car. As the maximum angle between car and camera is considered to be 70 degrees, we suggest using equation (2) in order to obtain the minimum and maximum value for the aspect ratio as well:

$$\begin{cases} \textit{Minimum aspect ratio} = 5\times\cot(\text{maximum angle}) \\ \textit{Maximum aspect ratio} = 5/\cot(\text{maximum angle}) \end{cases} \quad (2)$$

where $\cot(x)=\cos(x)/\sin(x)$.

Therefore, the maximum and minimum aspect ratios of Iranian license plates regions are 13.7 and 1.8 respectively. In addition, we consider the smallest value for the Iranian license plate area equal to 0.55 and the smallest size equal to 10×50 pixels. Then the candidate license plate should have at least 275 (0.55×10×50) pixels. In this paper, we consider these two features (aspect ratio and the smallest plate size) to discard, some more regions before arriving in element analysis, Fig. 4 shows the result. Comparing Fig. 3 with Fig. 4 we see more candidate regions are discarded but still there are many regions those are not license plates and should be omitted. Next section, we detect the accurate license plate by using element analysis.

### 2.3. Analyzing Region Elements

In section 2.2 many regions were candidated as being the license plate and in this part, we employ the region elements analysis in order to detect the license plate accurately. In general, we analyze every candidate regions in order to check if there are any character strings inside. The region elements analysis includes four stages: binarization, character geometric analysis, character continuity analysis, and at last character parallelism analysis.

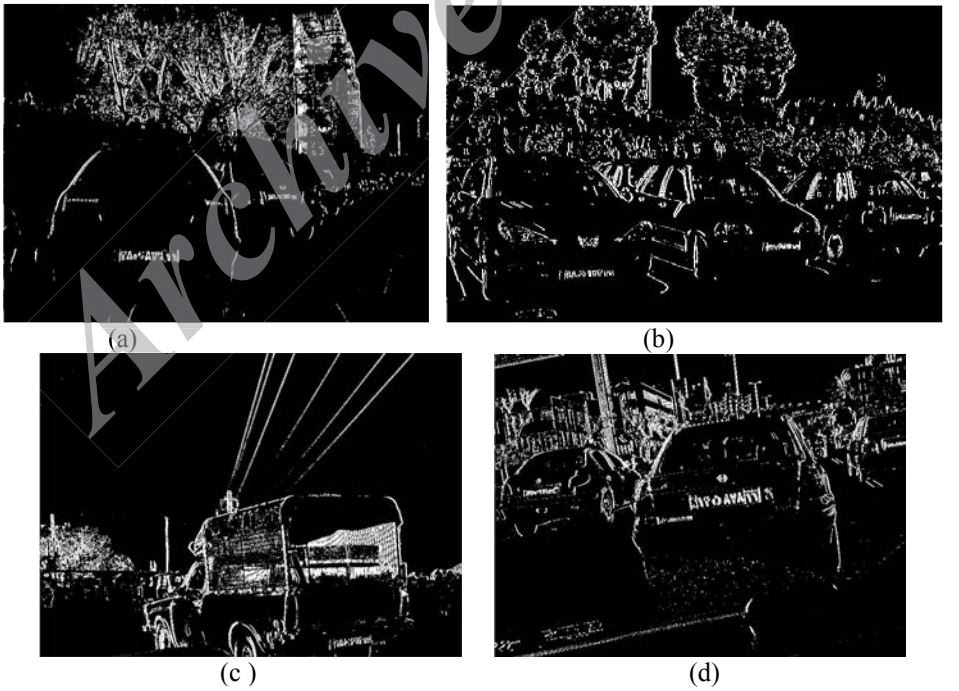
***Binarization***

We need to define an appropriate threshold to convert any gray image to a binary image. For this purpose, we consider the average values of illumination in every candidate region as thresholds. It means we use the local threshold for each region and so every candidated region is converted to binary, adaptively. After image binarization, the 8 neighbors connect component algorithm are applied for image segmentation and extracting the elements. This method scrolls the image pixels from left to right and from top to bottom to extract the connected pixels.

(a) (b)

(c ) (d)

**Fig. 1.** Four samples of original images belong to our database.



(a) (b)

(c ) (d)

**Fig. 2.** Extracting edges by using vertical Sobel mask.

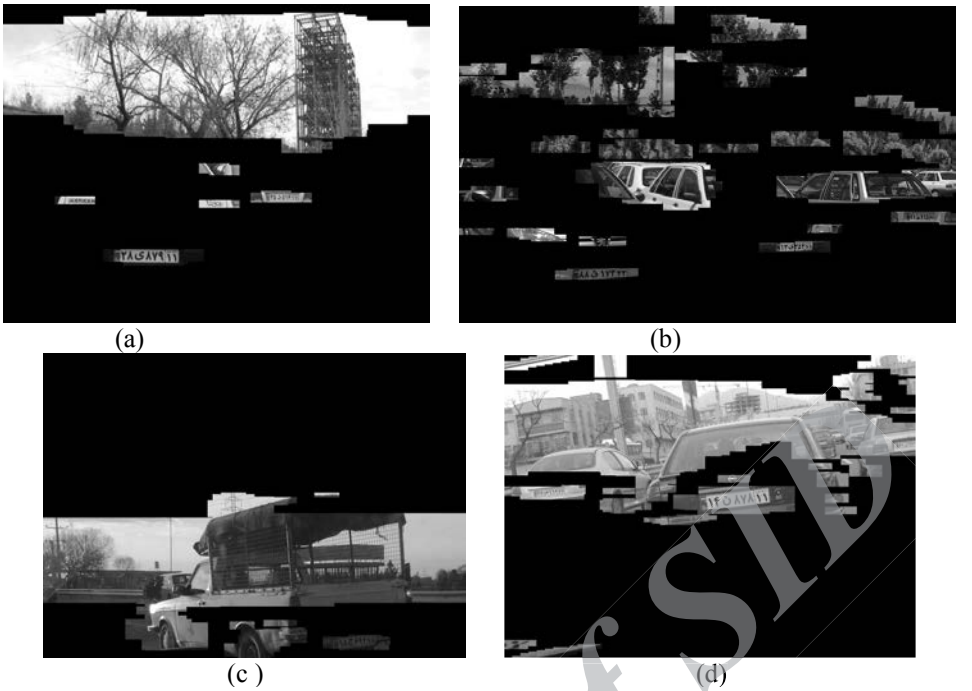


**Fig. 3.** Moving windows, many regions in addition to the license plate are candidated.

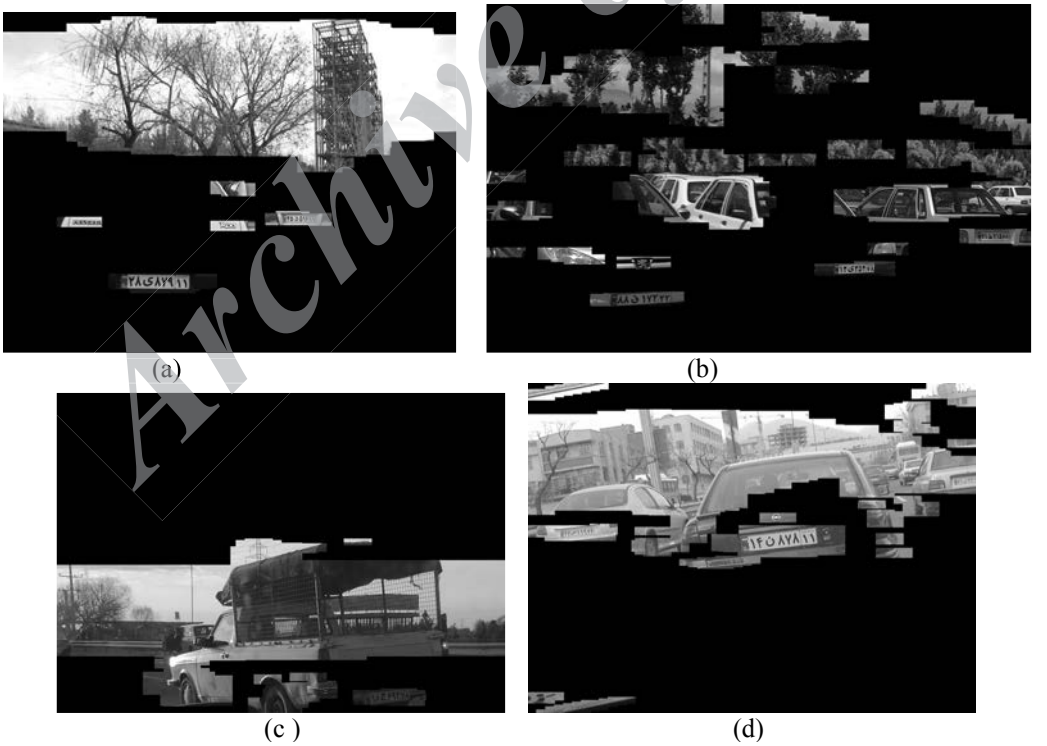


**Fig. 4.** Results of obtaining candidated regions, there already existed some other regions except license plate.

Each group of connected pixels is identified as one element in selected region. In following, we analyze the obtained elements and evaluate the similarity of these elements with license plate characters.

Although there are 32 characters in Iranian language, just 16 characters are used to identify the Iranian license plates. These characters are written in table 1. In addition, the Iranian vehicle license plates

are categorized to three different classes. They are private that has an owner, public that is used for public transportation, and governmental that belongs to the government. Although each class has a different background plate color, all use 7 numbers in order to obtain a unique license plate. A sample of every plate is shown in Fig. 5. In this paper, we work on private Iranian license plate detection, and then recognition though we believe our proposed algorithm can be used for the other two classes as well.

**Table 1.** Three types of Iranian license plate and their characters and colors.

| Plate type | Characters | Colors |
|---|---|---|
| private | ب، ج، د، س، ط، ص، ق، ل، م، ن، و، ه، ي | white-black |
| public | ت ، ع | yellow-black |
| governmental | الف | red-white |

**Fig. 5.** Three different classes for the Iranian vehicle license plate: the left is private; the middle is public; the right is governmental.

***Character Geometric Analysis***

This analysis considers two features, character aspect ratio and active pixels per character area (APR). The highest aspect ratio (width to height) in the Iranian standard license plates is related to the characters "ب" and "ت " and the lowest aspect ratio is related to number "1". These ratios in the worst possible conditions are 3 and 0.1, respectively. So each element can be considered to be a character if it's computed aspect ratio is in the interval [0.1 3].

Character area obtains with multiplying major axis by minor axis of character. This rectangule embeds on the character. On the other hand, active pixels are pixels that formed the character. Then for the second feature, we define the active pixels per character area or active pixels ratio (APR) as:

$$APR = \frac{active - pixels}{major - axis \times \text{minor} - \text{axis}} \qquad (3)$$

We have considered the Iranian license plate characters in different conditions and determined the maximum and minimum value for APR equal 0.75 and 0.2, in order.

***Character Continuity Analysis***

Obviously, those elements belong to a license plate set one after another. In other words, there is continuity between elements (that belongs to the plate) with before and after element, or the distance between license plate elements are not too much. Using this property as a feature, we use Euclidean distance for centers of mass elements as follows:

$$\sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2} < 1.1 \times major - axis \qquad (4)$$

$$\sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} < 1.1 \times major - axis \qquad (5)$$

where $x_i$ and $y_i$ are width and height of mass centers, and $major - axis$ is the biggest length (horizontal or vertical length) of element. The structure of Farsi characters requires that each center of a mass element locates between of two neighbor center of mass as smaller than 1.1 its $major - axis$. For the first element just inequality (4) is used and for the last element just inequality (5) is applied, whenever for other elements the both (4) and (5) are to be considered. Each element which does not satisfy the requirements would be removed from the region. The process is done iteratively until all remained elements satisfy the continuity requirements.

***Character Parallelism Analysis***

In this part, we evaluate the height and width of region elements. For Farsi characters, the height and width interval ratios via different situations in order are: [0.4 2.5]. Any not parallelism element with other elements should be removed from the region. Parallelism analysis is also an iterative process. At the end of the process, all the remaining characters will be similar in width and height. In addition, we notice that the number of Iranian license plate's characters is 8, so any region which includes less or more than 8 elements is not a license plate and must be removed.

**2.4. Detecting Plates and Compensating Rotations**

The first achievement of this work is detecting any Iranian license plate in an image based on using the element analysis. The results for the four different chosen images are shown in Fig. 6. As it can be seen, although these four images are captured in different conditions, our proposed algorithm can detect the license plates as well. Anyway, there is not a standard bank for Iranian license plate, so we prepared the database which includes 200 images. The images are captured in different conditions: camera distance (short and normal), camera angle (low and high), low resolution (dirty, reflection, and deformed plates), and multiplicity of plates in the image. We have run the explained algorithm and the license plates are extracted correctly in 194 images. So the total accuracy achievement by our detection approach is 91%.

(a) (b)

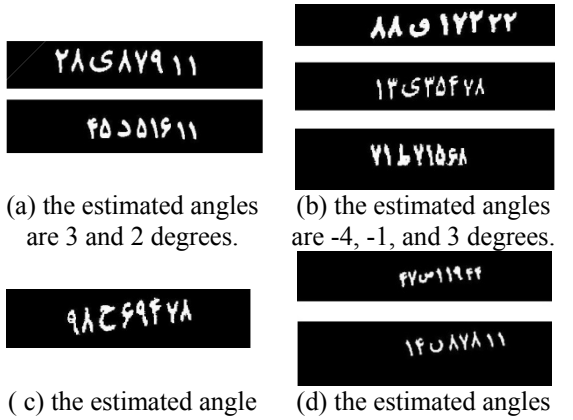
(c ) (d)

**Fig. 6.** The results of region elements analysis for the, for low contrast images, (c ) and (d), the algorithm succeeded to detect the license plate.

Extracted plates may have an angle with the horizontal or even vertical line. If we estimate the rotation angle, then compensation is possible. Therefore, we label all the elements of a detected plate according to use 8 neighbor connected component, which was explained in section 2.3. Then, we compute the central mass of each element and compute angle between every side by side element via using equation (6):

$$angle = arctg(\frac{vertical - difference}{horizontal - difference}) \quad (6)$$

where $vertical - difference$ and $horizontal - difference$ refer to the vertical and horizontal mass difference of the two side by side elements (the reference point with coordinate (0, 0) are considered to be at left-up hand of a detected plate). As we know, any license plate includes just 8 characters, Therefore, after computing 7 angles between elements, we determine the average rotation angle and we rotate counter clockwise. The detected and cropped plates are shown in Fig. 7, and the computed angles for every plate are also written. Fig. 8 shows the license plates that we have compensated the rotations. We believe this compensation would improve our accuracy of characters recognition.



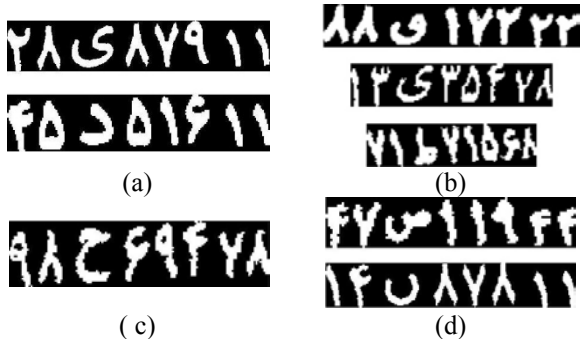
(a) the estimated angles are 3 and 2 degrees.

(b) the estimated angles are -4, -1, and 3 degrees.

( c) the estimated angle is -5 degrees.

(d) the estimated angles are -5 and -7 degrees

**Fig. 7.** The detected plates are cropped and shown and estimated angles are written in order from top to bottom



(a) (b)

( c) (d)

**Fig. 8.** Detected plates after compensating the rotation.

## 3. RECOGNIZING CHARACTERS

Character recognition means to specify exactly letters and numbers, which are in a region or in this work detected license plate. For this purpose, at first we should extract characters (the method described in section 2.3) and then recognize every 8 characters that there are in Iranian license plate. As we know, in order to distinguish characters, we need to define some features [8] - [11]. In this work, we extract 25 features that derived from zoning, geometric, and statistical analysis as well.

### 3.1. Zoning Features

For every particular character, we have done lattice, vertical and horizontal zoning as well and derived 13 features, totally. Before describing how zoning works, we mention that each character is embedded by a rectangle with a known size. First for lattice zoning, a character region is divided to four equal parts as shown in Fig. 9. Then, we compute the amount of active pixels for every region according to equation (7) and obtained 4 lattice zoning features.

$$Z_i = \frac{(active-pixels)_i}{total-pixels} \qquad i = 1,2,3,4 \qquad (7)$$

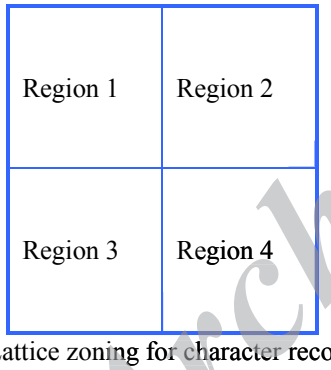



**Fig. 9.** Lattice zoning for character recognition.

As the image is binary, $active-pixels$ are those with value 1 and the $total-pixels$ refers to a character size or embed rectangular size, perfectly. In addition to four features that obtained from each region, we determined 3 other features by employing equation (8) as follows:

$$Z_{ud} = \frac{Z_1+Z_2}{Z_3+Z_4} \qquad Z_{lr} = \frac{Z_1+Z_3}{Z_2+Z_4} \qquad Z_{udlr} = \frac{Z_1+Z_4}{Z_3+Z_2} \qquad (8)$$

In this way 7 features are obtained from lattice zoning. Although lattice zoning has applied for recognizing Arabic characters before, the above 3 suggested features (equation (8)) never have been used by researchers. If we divide a character area to three equal parts once along vertical axis and once along horizontal axis as shown in Fig. 10, it named vertical and horizontal zoning. We calculate the zoning features according to equation (7) for every region and derive 6 features. Then, at the end of zoning process, we obtain 13 features for each character.

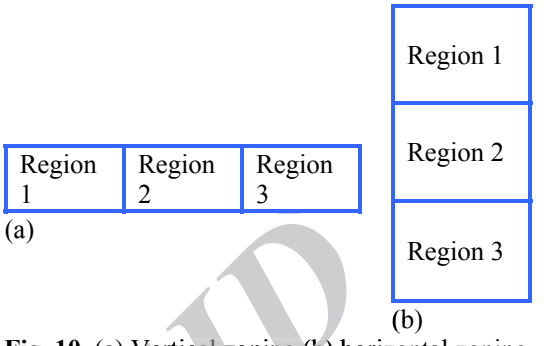



**Fig. 10.** (a) Vertical zoning (b) horizontal zoning.

### 3.2. Statistical Features

At the second step of feature extraction, we consider the statistical characteristics of character [11]. In this section, we study the statistical properties related to the vertical projection and the horizontal projection of characters. Horizontal projection means that moving on the horizontal axis and calculating projection of columns. Vertical projection means that moving on vertical axis and calculating projection of rows. To perform this purpose, first we draw the vertical and horizontal histogram and then calculate the statistical characteristics of them. In order to draw these histograms, we calculate sum of the active pixels in each vertical and horizontal lines. It is clear that the length of horizontal projection is the character columns and length of vertical projection is the character rows. Fig. 11 shows a sample of horizontal and vertical projection related to Farsi character "س" which is also used in previous steps. Statistical properties that can be extracted from these histograms are in according to equation (9)-(14):

$$m = \sum_{i=0}^{L-1} Z_i P(Z_i) \qquad (9)$$

$$\mu_2(Z) = \sum_{i=0}^{L-1} (Z_i - m)^2 P(Z_i) \qquad (10)$$

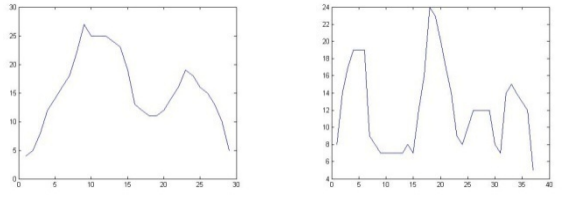
$$\mu_3(Z) = \sum_{i=0}^{L-1} (Z_i - m)^3 P(Z_i) \qquad (11)$$

$$\mu_4(Z) = \sum_{i=0}^{L-1} (Z_i - m)^4 P(Z_i) \qquad (12)$$

$$U(Z) = \sum_{i=0}^{L-1} P^2(Z_i) \qquad (13)$$

$$e(Z) = \sum_{i=0}^{L-1} P(Z_i) \log_2 P(Z_i) \quad (14)$$

where m is mean, $\mu_2(Z)$ is variance, $\mu_3(Z)$ is the third order of central moment, $\mu_4(Z)$ is the fourth order of central moment, $U(Z)$ is a criterion for uniformity, and $e(Z)$ is entropy of histogram. In addition $L$ in horizontal histogram refers to the number of columns and in vertical histogram refers to the number of rows and $P(Z_i)$ is the probability that class i occurs. In this way, we determine 6 features for each horizontal and vertical histogram.



(a) (b)

**Fig. 11.** Sample of horizontal and vertical projection related to character "س " (a) vertical projection (b) horizontal projection.

### 3.3. Recognition Experimental Results

During character analysis in section 3.1 and section 3.2, we have obtained 25 features (zoning features are 13, and statistical are 12). In order to recognize an unknown character we should use a classifier. We found neural networks may be the best. As there is just one letter in Iranian license plate as shown in Fig. 5, we employ two neural networks to recognize letters and numbers as well. The first classifier is for recognizing the numeric characters and contains 25 neurons in input layer, 30 neurons in middle layer and 9 neurons in output layer. Second classifier is for recognizing the alphabetic characters and contains 25 neurons in input layer, 35 neurons in middle layer and 13 neurons in output layer. Number of neurons in middle layers obtains by try and error. We have run the recognition algorithm on those plates that we detected them correctly. In addition even one character does not recognize correctly we consider the algorithm has been failed. It is easy to compute that our algorithm for classification fails just for 15 images while the total numbers of processing images are 194. It means we achieved accuracy equal 92.2% in average.

## 4. CONCLUSION

We presented an accurate method for detection and recognition the Iranian license plates. It is robust to problems such as varying the distance and angle between the vehicle and the camera or dirty deformed plates. In addition, the method can be used for images including more than one car. The proposed algorithm for license plate detection has been run on the provided database which includes 200 images and the obtained average accuracy is appropriate. We have also employed the artificial neural network classifier to recognize characters. Although the algorithm has been used for Iranian license plate detection, we believe it can be used for numerical signs and municipality plates as well.

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