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# Artificial neural networks based vehicle license plate recognition

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**Abstract**

In recent years, the necessity of personal working in traffic control is increasing because the numbers of vehicles in traffic is increasing. To deal with this problem, computer based automatic control systems are being developed. One of these systems is automatic vehicle license plate recognition system. In this work, the automatic vehicle license plate recognition system based on artificial neural networks is presented. In this system, 259 vehicle pictures were used. These vehicle pictures were taken from the CCD camera and then the license plate region dimensioned by 220x50 pixels is determined from this picture by using image processing algorithms. The characters including letters and numbers placing in the license plate were located and determined by using Canny edge detection operator and the blob coloring method. The blob coloring method was applied to the ROI for separation of the characters. In the last phase of this work, the character features were extracted by using average absolute deviation formula. The digitized characters were then classified by using feed forward back propagated multi layered perceptron neural networks. The correct classification rates were given in last section.


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*Keywords:* Vehicle licence plate recognition, artificial neural networks, blob coloring, character recognition.

## 1. Introduction

Within the fast developing countries, the number of vehicles is increasing day by day. In parallel to this, the need to recognize the vehicles and their license plates is increasing. To supply this necessity, computer based automatic vehicle license plate recognition systems are being developed recently. In this study, we proposed an efficient automatic vehicle license plate recognition system based on artificial neural networks (ANN). This system consists of three major topics. These are; localizing the plate region from the car image, segmenting the characters from the license plate image and recognizing the segmented characters. The block scheme of the proposed automatic license plate recognition system is shown in Fig 1.

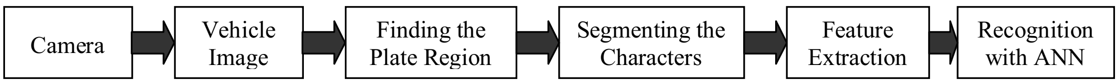


Fig. 1. The block scheme of an automatic license plate recognition system

The layout of this work can be analyzed into 7 section. In section 1, the general information about this work was introduced, the previous works on license plate recognition was given as table in section 2. In section 3, localization


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process was described. The segmentation process of the characters was introduced in section 4. In section 5, the feature extraction process of the segmented characters were presented. The recognition of the characters by using ANN was presented in Section 6. The experimental results were presented in the last section of this work.

## 2. Previous Works

The previous works will be held according to the works on Turkish civil license plate recognition. The success rates (SR) for the stage of plate region localization (PRL), character segmentation (CS) and character recognition (CR) processes were given in Table 1 [1-6].

Table 1. Success rates of the previous works

| Author | Year | Number of Image Used | SR for PRL (%) | SR for CS (%) | SR for CR (%) |
|---|---|---|---|---|---|
| H. Caner | 2006 | 42 | 92,85 | 87,17 | 94,12 |
| S. Ozbay | 2006 | 340 | 97,65 | 96,18 | 98,82 |
| G. Yavuz | 2008 | 80 | 92 | 95 | 90 |
| B. Yalim | 2008 | 200 | 96 | - | 92,5 |
| I. Irmakci | 2008 | 145 | 96,55 | 96,61 | 95,25 |
| K. Bora | 2009 | 225 (plate) | - | 100 | 89,33 |

## 3. Localization of the Plate Region

The first stage of license plate recognition system is finding the plate location from vehicle image. The plate region consists of white background and black characters normally. Therefore, the transitions between black and white colors is very intensive in this region. Finding the region that includes most transition points would be adequate for localizing the plate region.

For this purpose, Canny edge detection operator was applied to the vehicle images to get the transition points. The Canny edge detector uses a filter based on the first derivative of a Gaussian smoothing. After smoothing the image and eliminating the noise, the next step is to find the edge strength by taking the gradient of the image. For this process, this operator uses 3x3 dimensioned matrices. The edge strength of the gradient is then calculated. This information gives us the edge points, so the intensive transition points region can be determined. The transition points between black and white colors was then determined from this edge map. The original, the edge detected and the localized plate region images were shown in Fig 2a, 2b and 2c respectively.

Fig. 2. (a) original car image; (b) edge detected; (c) localized plate region

## 4. Segmentation of the Characters

The gray level license plate image should be enhanced before segmentation process. Because the contrast differences can be occurred while taking the images by camera. Also, unwanted dirty regions can be placed on the plate and these noises affects the segmentation process in negative direction.

In this work, the gray level plate images were enhanced by applying contrast extension and median filtering techniques. So, the contrast differences between images and the noises such as dirty regions in white background of the plate can be eliminated. After image enhancement phase, the blob coloring method was implemented to determine the boundaries of the characters.

### *4.1. Contrast extension*

To extend the contrast of an image means equalization of the histogram of that image. In other words, the contrast extension makes the image sharpen. The gray-level histogram of an image is the distribution of the gray level values in an image. The histogram equalization is a popular technique to improve the appearance of a poor contrasted image.

The process of equalizing the histogram of an image consists of 4 steps [7]: (1) Find the sum of the histogram values. (2) Normalize these values dividing by the total number of pixels. (3) Multiply these normalized values by the maximum gray-level value. (4) Map the new gray level values. The contrast extended license plate image is shown in Fig 3b.

### *4.2. Median filtering*

Median filter is used for eliminating the unwanted noisy regions. In this filtering method, the 3x3 matrices is passed around the image. The dimension of this matrices can be adjusted according to the noise level.

The process is working as [7]; (1) one pixel is chosen as center pixel of the 3x3 matrices, (2) the arounding pixels are assigned as neigborhood pixels, (3) the sorting process are employed between these nine pixels from smaller to the bigger, (4) the fifth element is assigned as median element, (5) these procedures are implemented to the all pixels in plate image. The filtered plate image is shown in Fig 3c.


Fig. 3. (a) original plate region image; (b) contrast extended image; (c) median filtered image

### *4.3. The blob coloring method*

The blob (Binary Large Object) coloring algorithm has a strong architecture to determine the closed and contacless regions in a binary image. This algorithm uses a special L shaped template to scan the image from left to right and from up to down. This scanning process determine the independent regions by obtaining the connections into four direction from zero valued background. In this work, four directional blob coloring algorithm is applied to the binary coding license plate image for getting the characters [8]. After implementation, the segmented characters were obtained from the license plate region image (Fig 4).


Fig. 4. The segmented characters

In this work, the segmented characters were classified as numbers and letters separately. For this purpose, the plate image was divided into three region. The first region consists of two digit numbers that indicates the city traffic code. The second region consists of one-to-three digit letters. The third region consists of two-to-four digit numbers. The plate image was scanned form left to right horizontally and the spaces between characters were determined in this process. If the value of the space is higher than threshold value than the character region is signed. The numbers were localized as 28x35 pixels dimension. The letters were localized as 30x40 pixels dimension. Some samples of numbers and letters segmented from plate region are shown in Fig 5.


Fig. 5. Some samples of the segmented characters

## 5. Feature Extraction

In this study, the obtained characters were saved as an image file separately. The dimension of the numbers was determined as 28x35 pixels, the dimension of the letters was determined as 30x40 pixels. The numbers and the letters were classified by using two separate ANN for increasing the success rate of the recognition phase. Before classification, the character images should be feature extracted. Feature extraction provides us to obtain the most discriminating information of an image. This information can be presented as a feature vector. A feature vector that includes global and local features of an character should be encoded so that the comparison between characters can be made. In the proposed approach, the feature vector of an iris image was encoded by using Average Absolute Deviation algorithm [9]. This algorithm is defined as:

$$V = \frac{1}{N}\left(\sum_{N}\left|f(x,y) - m\right|\right) \tag{1}$$

where N is the number of pixels in the image, m is the mean of the image and f(x,y) is the value at point (x,y). In this work, the number images were divided into 4x5 pixels dimensioned sub-images and the letter images were divided into 5x5 pixels dimensioned sub-images. Each sub-image were feature extracted by applying AAD. We obtained the feature vectors with the length of 49 byte for numbers and 48 byte for letters. The entire feature vectors were applied to the ANN as an input for classification of the characters.

## 6. Recognition of the Characters

In our work, the numbers and the letters were classified by using two separate ANN for increasing the success rate of the recognition phase. Both of them have same architecture but only the input numbers were differed. The reason for using two separate ANN for recognition is preventing the complexity of recognition of similar numbers and letters such as “0” – “O”, “2” – “Z” and “8” – “B”. As we can know, this complexity will decrease the recognition success.

In the proposed approach, a multi layered perceptron (MLP) ANN model was used for classification of the characters. The processing units in MLP are arranged in three layers. These are input layer (includes the information you would use to make decision), hidden layer (helps network to compute more complicated associations) and output layer (includes the resulting decision) [10,11]. Each neuron in the input layer is fed directly to the hidden layer neurons via a series of weights. The sum of the products of the weights and the inputs is calculated in each node. The calculated values are fed directly to the output layer neurons via a series of weights. As in hidden layer, the sum of the products of the weights and the hidden layer neuron outputs is calculated in each node in the output layer. If the error between calculated output value and the desired value is more than the error ratio, then the training (changing the weights and calculating the new output by using the new weights) process begins. This training process can be finished by obtaining the desired error rate for all input combinations.

For training the ANN, feed-forward back-propagation algorithm was chosen. For measuring the training performance of the network, mean square error (MSE) function is used. The value of the MSE is used to determine how well the network output fits the desired output. The stop criteria for supervised training are usually based on MSE. Most often the training is set to terminate when the MSE drops to some threshold. Approaching the MSE value to the zero means that the calculated output value is becoming the closer to the desired output value.

## 7. Experimental Results

In order to evaluate the performance of the proposed system, 259 vehicle images were employed. Sigmoid function is used in the activation of neurons. Quick back propagation learning algorithm was used for training the ANN. Maximum 5000 iterations were performed for each input set. When the system reach to the minimum error rate which defined by the user, the iterations will be stopped. The defined minimum error rate for this application is 0,001. Only one of the input images was used for testing the system, the rest was performed in training phase. The iteration-MSE graphics of best results for each character data set are shown in Fig 6. The training reaches the minimum error rate in 4457 iterations for the numbers and 1180 iterations for the letters.

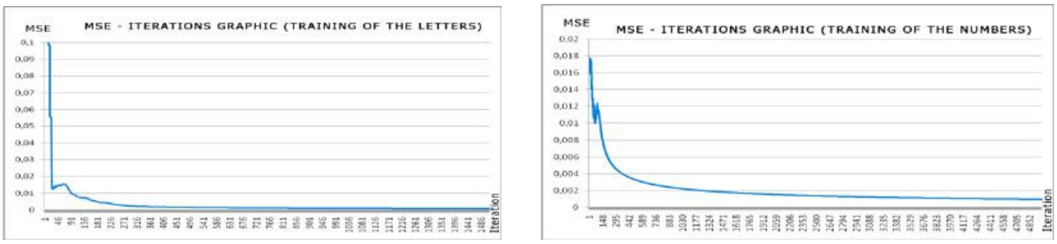


Fig. 6. MSE – Iterations graphics of the training process

The success rates for the plate region localization (PRL), character segmentation (CS) and character recognition (CR) stages of the proposed system are given in Table 2. As a result, 247 license plates in 259 vehicle image were recognized correctly in this work, so the overall recognition percentage of the system is 95,36%.

Table 2. The success rates of the proposed automatic license plate recognition system.

| Stage | Number of Samples | Number of Correct Results | Success Rate (%) |
|---|---|---|---|
| PRL | 259 | 255 | 98,45 |
| CS | 255 | 252 | 98,82 |
| CR | 347 (Letters) + 1022 (Numbers) | 344 (Letters) + 1000 (Numbers) | 98,17 |

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