MVSR Normalization Algorithm Method for Improving Vehicle License Plate Recognition

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Abstract: Image processing and embedded systems are used in many applications such as object recognition, robotic applications, autonomous and remote control systems developed for the defense industry, medical applications, face recognition, and vehicle license plate recognition. Many vehicle license number plate detection methods are not effective under vehicle license plate images have a degree of rotation or low resolution images. Thus, we used MVSR normalization algorithm to detect vehicle license plate recognition for better accuracy and lower computational cost. The MVSR normalization algorithm, Mean–Variance-Softmax-Rescale processes respectively is applied for high-accuracy real-time vehicle license plate detection.

Key words: MVSR algorithm, vehicle license plate recognition, normalization, artificial neural network.

Araç Plaka Tespitinin İyileştirilmesine Yönelik MVSR Normalleştirme Algoritması Yöntemi

Öz: Görüntü işleme ve gömülü sistemler; nesne tanıma, robotik uygulamalar, savunma sanayi için geliştirilen otonom ve uzaktan kontrol sistemleri, medikal uygulamalar, yüz tanıma, araç plaka tanıma gibi birçok uygulamada kullanılmaktadır. Dönme derecesine sahip veya düşük çözünürlüklü görüntülere sahip araç plaka görüntüleri altında birçok araç plakası tespit yöntemi etkili değildir. Bu nedenle, daha iyi doğruluk ve daha düşük hesaplama maliyeti için araç plakası tanımayı tespit etmek amacıyla MVSR normalleştirme algoritmasını kullandık. Yüksek doğruluklu, gerçek zamanlı araç plakası tespiti için sırasıyla MVSR normalleştirme algoritması, Ortalama-Varyans-Softmax-Yeniden Ölçeklendirme işlemleri uygulanmıştır.

Anahtar kelimeler: MVSR algoritması, araç plaka tespiti, normalizasyon, yapay sinir ağı.

1. Introduction

Vehicle license plate recognition systems are the feature extraction in the image processing applications. It is also both software and hardware-based applications designed to extract vehicle license plate characters from an image or a group of images (video). Therefore, the efficient application of license plate recognition systems has an important place.

In the literature, the study of Nagare [1], they used two different artificial neural networks to determine license plate numbers. After the image is obtained from the camera, some pre-processes (graying, morphological operations, etc.) are applied, and the license plate region is obtained. If the pixels in the same column in the plate region obtained after this step are white, the image cutting process is performed. In this way, pictures with only one license plate character are obtained. After this stage, classification of plate characters is carried out with the proposed LVQ (Learning Vector Quantization) neural network model. Car number plate characters were detected with an accuracy rate of 66.67% in the backward propagation learning model and 94.44% in the LVQ model proposed.

In the study carried out by Zhai and his working group [2], the detection of the plate region in the image was performed using the FPGA embedded system platform. The algorithm proposed in this study was first implemented in the MATLAB environment and then implemented on the RC240 FPGA development board. As a first step, the three-dimensional color image was converted to a grayscale image, then a vertical 3x3 Sobel filter was applied to this image. After this stage, they applied morphological closing with 3x22 structural elements and then morphological opening using 3x5 structural elements. They detected each plate region in the image with an accuracy rate of 99.1% and an average of 3.8 ms.

Indravadanbhai and his working group [3] performed plate reading applications used the OCR method. The disadvantages of this method are that the characters are close to each other, parts of the image with text are in the shade, and some characters are similar, for example, characters such as B and 8, O and zero, I and 1, A and 4, K and X, C and G, D and O. affect the reading accuracy. They carried out studies on image preprocessing (filtering, image enhancement, morphological operations, etc.) and character separation stages to reduce these effects.

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Car number plate standards are vary by sizes, colors, and languages used (latin, arabic, chinese characters, etc.). In the studies carried out by Du, Massaud and their study group [4, 5], the recognition of plate characters consisting of Egyptian Arabic letters was carried out. For the detection of the plate region,

- Obtaining the image through the camera
- Converting a color image to a grayscale image
- Implementation of Sobel edge detection algorithm
- Realization of morphological opening and closing operations
- Filling the closed areas in the image
- Applying the 5x5 Median filter to the image

Detection of the plate region by eliminating the closed regions that do not fit the standard plate dimensions.

After the plate region was determined, morphological dilation was applied to increase the distances between the characters in order to distinguish the plate characters appropriately. After the plate characters were separated, the image of each character was converted to the specified standard dimensions. By using the template matching technique, the obtained character images were identified using the statistical correlation (correlation) method. They were defined by the normalized cross-correlation technique between pairs of images representing two separate images, which respectively specify the image to be searched and the template. This system is designed using GUI and UDP under MATLAB software. The proposed system was implemented with 100 image sets with 91% accuracy.

Zhang and his work group [6] used the Support Vector Machine (SVM: Support Vector Machine). This model separates classes from each other by vector space-based classification. After detecting the plate area using the SVM model, the characters were separated from each other using the projection technique and the plate numbers were determined. Convolutional neural network and two classifiers supporting vector machine for multi-channel processing are designed to recognize Chinese characters, numbers and alphabet letters respectively. The images obtained from the camera, and later the plate region was extracted using image processing algorithms. The separation of the characters was carried out using the projection technique. Numerical and alphabetic characters were classified using the CNN model and the Chinese and SVM model. In this study, classification of license plate characters was performed with an accuracy of 99.2%.

Zhai and Bensaali [7] improved the parsing process of the characters after obtaining the license plate region in the image in order to read the license plate faster and more accurately. They used an advanced character parsing algorithm based on pixel projection and morphological operations. In this proposed system, with the application of image processing algorithms, the detection of the plate region, and the separation of the characters with the projection technique were performed with different data sets. After the character separation process, the characters in the plate region were determined by using the OCR technique.

Fan et al. [8], advanced Driver Assistance Systems (ADAS) were developed for road lane detection, automatic parking and detected unmanned vehicles. In this study, image processing algorithms are embedded on TMS320C6678 SoC and they work on lane detection and ADAS systems. The proposed linear strip detection system consists of two main parts; image pre-processing applications and Hough transform are used. In the pre-processing stage, the Gaussian filter is used to reduce small details by blurring the image, removing noise. Then, edge detection operations were carried out by applying the Sobel filter. Algorithm, SoC DSP TMS320C6678 multi-core processor, 1242×375 image resolution, 81 fps speed and 94.1% accuracy rate of tol lane lines were detected. In the study carried out by Calderon and his working group [9], they performed the plate determination process using a computer and FPGA card. It was realized by recognizing the yellow color of the plate region in the HSV plane using a special algorithm for Colombian plates.

In the study by Promrit and Wannarat [10], Real time road lane was determined using FPGA (Zybo board) embedded system platform. In this study, HT and Hyperbola, Bézier Curve, Dot plot, Dot plot and Hyperbola algorithms were compared and lane detection was performed. It has been determined which algorithm is more suitable in real-time applications. Four algorithms are experimentally compared to find the appropriate algorithm for real-time stripe detection on images acquired at 1920×1080 pixel resolution and 60 fps on FPGA Zybo card. Dot graph and Hyperbola technique yielded better results than the other two algorithms. Using these two techniques, the road lane was detected with 0% error rate. They showed that Point graph and Hyperbola algorithms are better for real-time lane detection in applications to be implemented on the FPGA platform.

In the study performed by Li and his study group [11], two sequential CNN models were used to determine the plate region and characterization. The advantage of this method is that after the license plate region (plate present/no license plate) is detected, missing character recognition will be eliminated due to errors that may occur in the character parsing process. A stepwise classification process was performed using two different CNN models. The location of the characters on the image with the first CNN model and the parts without the plate region with the second CNN model were eliminated and the plate region was determined. In this study, classification operations were performed on NVIDIA Tesla K40c GPU with 6GB memory using MatConvNet.

However, this method is not suitable for real-time detection of license plate characters due to its data processing speed. The training database used in this study is divided into three different subgroups for detection and recognition:

- AC: The camera is fixed and the vehicle in the image is at a constant or slow speed
- LE: The vehicle in the image was taken due to a traffic violation
- RP: The vehicle in the image was taken with a motion camera

Xie and his work group [12], problems such as remote acquisition of vehicle images or the plate area not perpendicular to the camera were suggested by CNN-based YOLO (You Only Look Ones) ANN model, after determining the angle of the license plate area relative to the camera and bringing it to a vertical position, the license plate area was determined by character separation method. The characters in the region were tried to be determined. In the original YOLO model, it only estimates the center coordinate, height, and width of each object. In this study, the proposed method is used to determine the angle information and the rotation angle of a given license plate image. Classification processes were performed with accuracy rates of 99.51%-99.43% and 99.46%, respectively, in three different data sets used for license plate tests.

In the study carried out by Hendry and Chen [13], vehicle license plate characters were tried to be determined by using the YOLO-darknet learning model. A six-character Taiwan license plate reading was performed. The characters are determined sequentially by scrolling on the image with the sliding window method. The results of three different image datasets are compared using the proposed model, and the best results were obtained in the AC dataset. The data processing rate for each plate was 800ms-1s, and the system detected an average of 98.22% accuracy in plate detection and 78% of plate characters in recognition of plate characters.

Viju [14], the vehicle license plate recognition system was realized by using K-Means (KM) clustering algorithm and Optical Character Recognition (OCR) technique. After detecting the plate region using basic image processing algorithms such as the median filter and KM, they determined the plate characters with the OCR technique. Yousif et al. [15] proposed a new method for plate recognition in image processing algorithms and an optimized neutronopic set (NS) based on genetic algorithm (GA). Using the NS set, they were able to better identify the plate images. They applied a k-means clustering algorithm to segment the characters in the plate region and a correlated component labeling analysis (CCLA) algorithm by grouping the appropriate pixels to extract each character effectively. After the plate characters were separated, all the pictures were converted to the specified size, and then the characters were matched and the plate was determined by using the statistical cross correlation method. Plate characters were determined with an accuracy rate of 96.67% in high resolution images and 94.27% in low resolution images.

Zhang and his work group [16], plate identification was performed using CycleGAN (Generative adversarial networks) model and LSTM (Long short-term memory) based array decoder. With this model, the characters were tried to be determined by using the image similarity feature in the images where the plate region could not be determined exactly. The stages of the proposed model;

- Detection of the plate region by applying the trained YOLOv2 model to the input image
- Detected license plate regions, feature matrices are obtained with a thirty-layer Xception network
- An intermediate feature map with the Xception model for detecting license plate characters is removed
- An LSTM model is used to detect license plate characters with these two feature matrices.

In the study carried out by Agbeyangi and his working group [17], license plate characters were determined using the Optical Character Recognition (OCR) technique using Open Computer Vision (OpenCV) open source libraries using Raspberry Pi. In the study performed by Fernandes and his working group [18], they used Tiny YOLOV3 to detect the plate region and OCR technique to determine the characters in the plate region. Using Jetson TX2 development board for two different data sets, plate characters were detected with 96.87% and 90.56% accuracy rates. In the study carried out by Izidio and his working group [19], they developed a license plate recognition system for Brazil using the CNN model. Tiny YOLOV3 and a second CNN model with an accuracy of 98.43% of the plate characters were used to determine the license plate region.

Castro and his work group [20], they used OpenVINO, an image processing-based artificial intelligence platform developed by Intel, to perform license plate recognition. They performed the separation and recognition of license plate characters by using the single shot detector (SSD) for their own work by extracting the features in the image with the convolutional neural network. With this method, faster plate characters can be determined by using fewer parameters. The results of license plate recognition and character separation of the proposed model are given. Plate characters were detected in 14 ms using a twelve-core Intel Xeon CPU (2.60 GHz) computer and OpenVINO, and 66ms using a Raspberry Pi.

In the study carried out by Weihong and Jiaoyang [21], the camera used, uneven lighting, unfixed shooting angle, different weather conditions (fog, rain, snow, etc.), the time the image was acquired (night, day), motion blur, and the pollution rate of the license plate area. In this study, suggestions and studies were compared in the

realization of license plate reading in pictures obtained in bad conditions. Ma and Zhang [22], the vehicle logo was determined by using the CNN structure in order to eliminate the errors that may occur while determining the places that may be the license plate area. Thus, they focused on the plate area and analyzed the plate numbers.

Table 1. Applications in the literature of vehicle license plate recognition systems

Recognition of plate area	Character seperation	Character Recognition	Platforms	Accuracy	Study
Color conversion, morphological operations	projection technique	NN, LVQ NN	-	66%, 94.44%	[1]
Color conversion, edge detection, morphological operations	Connected Component Analysis (CCA)	OCR	MATLAB, FPGA	99%	[2]
Color conversion, edge detection, morphology operations	Morphology, projection technique	Template matching	MATLAB	91%	[4, 5]
Basic image processing techniques	projection technique	CNN, SVM	-	99.2%	[6]
Color conversion, morphological operations	projection technique	OCR	MATLAB, FPGA	96.2%, 97.7%	[7]
CNN	projection technique	CNN	NVIDIA Tesla K40c	97.75%	[11]
R-CNN	-	-	MATLAB	100%	[23]
YOLO-darknet	-	-	GPU K40	99.5%, 99.43% 99.46%	[12]
YOLO-darknet	-	-	Nvidia GTX970 GPU	98.2%	[13]
K-Means	projection technique	OCR			[14]
Basic image processing techniques, Morphological operations	Neutrosophic set, K-means,	character matching	MATLAB	96.67%, 94.27%	[15]
YOLO	Xception	LSTM	-	97.3%, 98.3%, 91.9%	[16]
YOLO	-	OCR	Jetson TX2	96.87%, 90.56%	[17, 18, 19]

In Table 1, the methods used in the literature for license plate recognition are compared. It is observed that license plate identification rates are higher when using the open source libraries and embedded system platforms with GPU structure. Performing the determination of the plate region with deep learning models (YOLO, R-CNN, CNN, etc.) increases the accuracy rate.

2. Material and Method

Normalization is one of the commonly used techniques in image processing. These techniques are generally used as an image pre-processing step in applications such as improving the image, reducing the noise on the image and changing the colour distribution and making it occupy less space in the memory [23].

2.1. MVSR normalization technique

In the normalization techniques used in general, the normalized pixel values of the image can have positive or negative pixel values, and negative pixel values are eliminated in some cases (uint8 transformation, etc.). In order not to eliminate the effect of negative pixels as a result of the normalization process, the MVSR normalization technique is recommended. All detail about this technique is given reference [24].

$$\mu_{MVSR} = \frac{1}{M}\sum_{i=1}^{M} x_i \tag{1}$$

$$\sigma_{MVSR}^2 = \frac{1}{M}\sum_{i=1}^{M}\left(x_i - \mu_{MVSR}\right)^2 \tag{2}$$

$$x_i = \frac{x_i - \mu_{MVSR}}{\sqrt{\sigma_{MVSR}^2 + \delta}} \tag{3}$$

$$S(x)_i = \frac{e^{x_i}}{\sum_j e^{x_j}} \tag{4}$$

$$r_i = \frac{S(x)_i}{\max(S(x)_i)} * 255 \tag{5}$$

MVSR Normalization processes are shown in equation 1-5. After the inversion process is applied to the images, new pixel values are obtained by using the mean value of the pixels in equation 1, variance calculation in equation 2, and mean and variance values in equation 3. In order not to eliminate negative value pixels in the new pixels obtained, it is aimed to associate all pixel values with each other by using the softmax activation function given in equation 4. The values obtained after applying Softmax range from 0-1 to 0-255, and the pixel values for the new image were obtained by using equation 5.

2.2. License plate detection and character separation with standard image processing techniques

Considering the disadvantages of license plate recognition applications and the related systems (hardware and software) that should be used for license plate recognition, they are quite costly systems. As the distance between the license plate and the camera decreases in the images obtained by the camera, the cost of the license plate recognition systems decreases.

In license plate recognition systems, license plate identification processes begin when vehicles enter the reading area. The process of determining the license plate consists of three basic processes. The correct detection of the license plate depends on the successful execution of these processes.

- Detection of the plate area
- Separation of characters in the license plate region
- Recognition of license plate characters

The vehicle license plate area was determined by applying image processing techniques on the images that are at different angles to the camera and obtained at a right angle to the camera. With the use of standard image processing techniques, accurate determinations can be made depending on the distance and angle information between the camera and the plate area in the detection of the license plate.

It was performed using standard image processing techniques on the image obtained from different angles. However, it is not sufficient to use basic image processing techniques in detecting the license plate region. Therefore, it is recommended to use different techniques (deep learning-based).

2.3 Detection of vehicle plate region and separation of characters with MVSR technique

It should be considered that the disadvantages of license plate recognition applications and the structures (hardware and software) that should be used for license plate recognition are quite costly systems. As the distance between the license plate and the camera decreases in the images obtained by the camera, the cost of the license plate recognition systems decreases.

Detection of the license plate area on vehicle images obtained from different angles and obtained from Microsoft Research Cambridge Object Recognition Image Database [25] and its stages are shown in Figure 2. Stages of detecting the plate region;

- Converting the original image to a grayscale image
- Application of MVSR normalization technique to grayscale image
- Obtaining the black-and-white image with the threshold value application
- Inclusion of the parts that can be the candidate license plate area in the rectangular regions
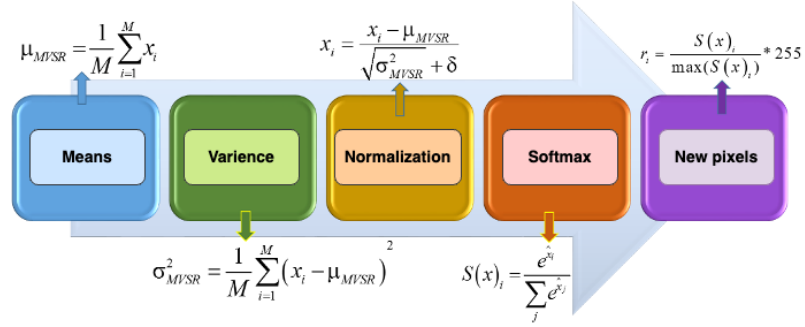- Detection of candidate plate regions by plate aspect ratio

$$\mu_{MVSR} = \frac{1}{M}\sum_{i=1}^{M} x_i \qquad x_i = \frac{x_i - \mu_{MVSR}}{\sqrt{\sigma_{MVSR}^2 + \delta}} \qquad r_i = \frac{S(x)_i}{\max(S(x)_i)} * 255$$

| Means | Varience | Normalization | Softmax | New pixels |

$$\sigma_{MVSR}^2 = \frac{1}{M}\sum_{i=1}^{M}(x_i - \mu_{MVSR})^2 \qquad S(x)_i = \frac{e^{\hat{x}_i}}{\sum_j e^{\hat{x}_j}}$$

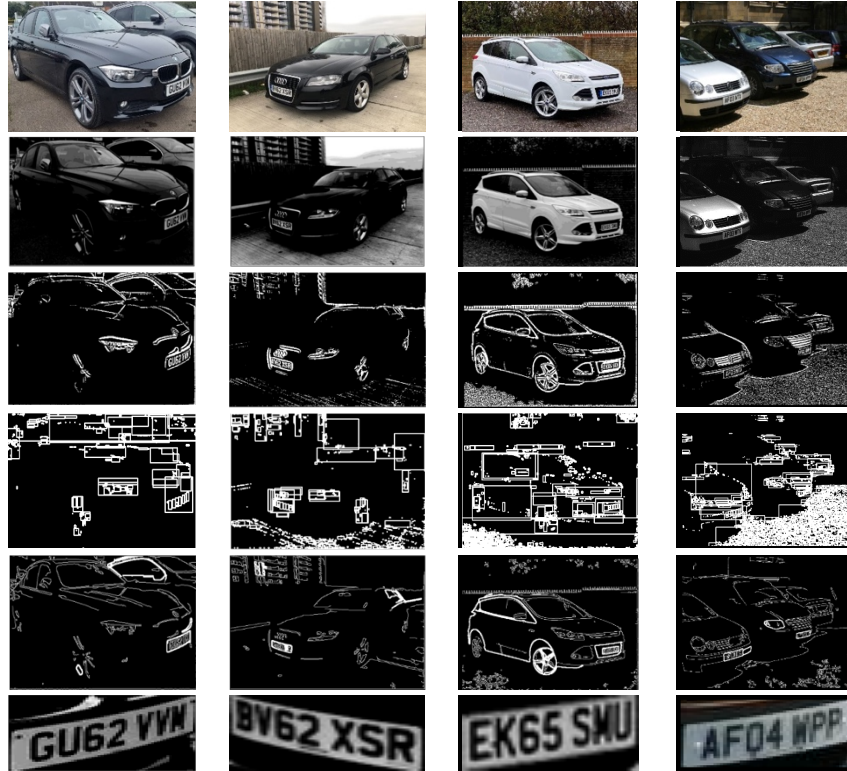**Figure 1.** MVSR normalization technique

Figure 2. Detection of license plates with different angles by MVSR normalization

The operations of removing the plate region from the image were performed. When the license plate area detection processes were performed without applying the MVSR normalization technique, which is the 2nd step, in the vehicle license plate determination process shown with the step above, the detection of the license plate region could not be performed. However, after applying MVSR normalization, detection of license plate regions can be performed in vehicle images taken from different angles. The determination of the plaque region in the images obtained from different angles was achieved at a rate of 95%.

After the candidate plate regions are determined in Figure 2, at this stage, the sizes of the obtained candidate plate regions are equalized. After applying the adaptive herbaceous algorithm, whose threshold value changes

according to the image, to the candidate regions, an image consisting of black and white pixels will be formed and thus blurring will be eliminated. By applying the morphological opening process to these regions, the distances between the objects in the image are increased (connections are broken), and then the white pixels that do not separate from each other in the row and column are enclosed in a rectangle. Images containing more or less rectangles than the maximum number of characters (seven) found in Turkey's private license plates [26] will be eliminated and the plate region will be determined or image(s) with shapes that cannot be plate region will be obtained.

Table 2. Comparison of detection of license plate area with different image processing techniques

Detection of plate area	Seperation the characters	Accuracy	Studies
Color conversion, morphological operations	projection technique	66%	[1]
Color conversion, edge detection, morphological operations	Connected Component Analysis (CCA)	99%	[2]
Color conversion, edge detection, morphology operations	Morphology, projection technique	91%	[4, 5]
Basic image processing techniques	projection technique	99.2%	[6]
Color conversion, morphological operations	projection technique	96.2%	[7]
MVSR	projection technique	95%	Present study

In Table 2, a comparison of different image processing techniques and applications of detecting license plate area in the literature is given. By using standard image processing techniques in the detection of the plate region, the detection of the plate region was carried out at lower regions. In applications where high percentages of candidate plate regions are realized, there is very little distance between the camera and the plate region and there is no background noise.

In applications carried out using deep learning models (YOLO, R-CNN and CNN etc.), the detection of the license plate area can be achieved at very high rates. In this respect, it is seen that the efficiency of the proposed technique is higher when compared to the applications in the literature performed with only the image normalization technique and the detection of the plate region using the proposed MVSR normalization technique. In the process of detecting the license plate area, the license plate areas that could not be detected in standard methods were determined by the proposed method.

2.4. Classification of license plate characters using CNN model
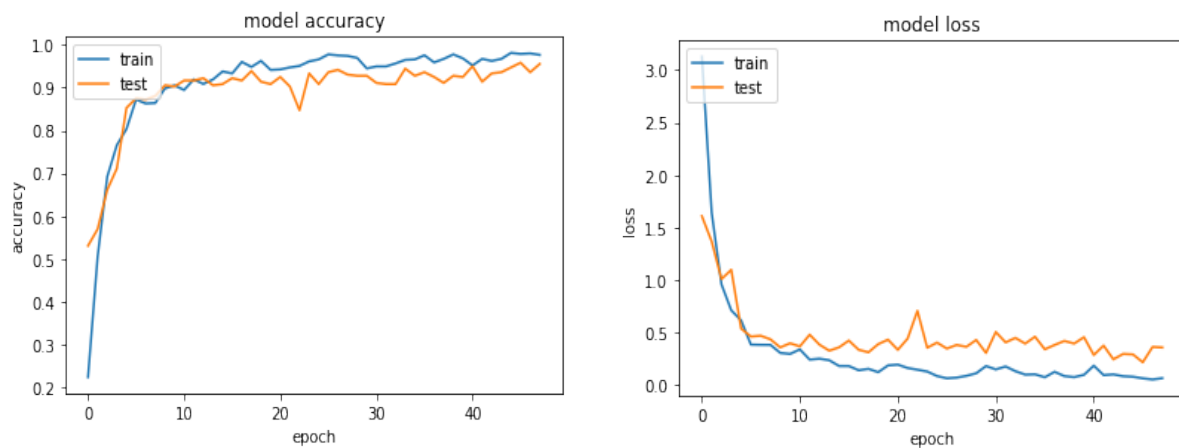
In the license plate recognition system, a convolutional neural network (CNN) model was used to find the license plate region and to determine the characters in the plate region after the characters were separated. Images for this model tutorial are taken from vehicle images. The dimensions of each image obtained were rearranged as 32x32x3.

The structure of the CNN model used in the training of thirty-three different characters (ten numbers and 23 letters) that can be found in the license plate area is shown in Table 3. Batch-Norm technique and ReLU activation function are used after convolution process in convolution layers (Conv1...). The classification process in the output layer is performed using the softmax activation function. The mean square error is used in the calculation of the error function.

At the separation of the vehicle license plate character process, each character will be passed through the model one by one and the detection process will be carried out. The accuracy of the generated CNN model will also determine the result of the license plate recognition system. Therefore, the model training result should be high. CNN model, 1240 images of 32x32 pixels, consisting of letters and numbers, were classified with 48 cycles (Epoch). Figure 3 show the accuracy and loss graphs of the license plate characters, depending on the number of model cycles. As a result of the training, the model accuracy rate was 98.54% and the loss was 0.074.

Table 3. Design of the CNN model created for plate characters

Layers	Layer Configurations			
	S	N	W	H
Input	-	-	32	32
Conv1	3x3	32	32	32
Conv2	3x3	32	32	32
Conv3	3x3	64	32	32
Max-pool.	2x2	-	16	16
Conv3	3x3	128	16	16
Max- pool.	2x2	-	8	8
Conv4	3x3	64	8	8
Max- pool.	2x2	-	4	4
Flattening.1	1024			
Flattening.2	512			
Flattening.3	256			
Output	33			

Figure 3. CNN model accuracy and loss

3. Conclusions

In the realization of the detection the license plate area, in the applications performed using standard image processing techniques, in some cases, it is not possible to perform the license plate detection operations under difficult conditions.

The MVSR normalization technique was used instead of the gaussian and bilateral filtering techniques used in determining the license plate region. By using this method, the number of candidate regions without license plate regions has been considerably reduced. Thus, the processing load to be performed has been reduced and less energy consumption and faster detection of the license plate area has been achieved. In addition, in difficult conditions (the camera sees the license plate area at different angles), the rate of obtaining the license plate area has been increased.

During the filtering (gaussian, bilateral, etc.) phase of the determination of the license plate area, some license plate areas that could not be determined before were successfully detected with the application of the MVSR normalization technique. Thus, after applying the proposed MVSR normalization, the detection of the plate region was achieved with 95% accuracy in some images that could not be determined by negative effects such as the distance and angle of the plate region relative to the camera. The results obtained with the application

of MVSR normalization When compared with the other applications in the literature, better results were obtained than the applications performed with only standard image processing techniques.

The use of basic image processing algorithms is not recommended in detecting the license plate region. As the distance between the camera and the license plate increases, the number of regions that can be plate regions will increase, so it will be difficult to detect the actual plate region and cannot be found. The MVSR normalization technique was used instead of gaussian and bilateral filtering techniques in determining the license plate region. By using the studied method, the number of candidate regions without license plate regions has been considerably reduced. Thus, the processing load to be performed has been reduced and faster vehicle plate area detection processes have been carried out with less energy consumption. After applying the proposed MVSR normalization, the detection of the license plate region was achieved with 95% accuracy in images that could not be determined by standard image processing techniques with negative effects such as the distance and angle of the plate region relative to the camera. However, it is recommended to detect plate region determination processes using deep learning models (R-CNN, CNN, etc.).

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