



Car license plate detection by color processing and edge detection methods

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Original Research

Abstract:

Received:
15 October 2024
Revised:
7 November 2024
Accepted:
10 November 2024
Published online:
30 December 2024

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One of the main processes in intelligent transportation systems is car license plate detection. The most important part of this algorithm is detecting the blue part on the left side of license plates. After identifying the blue part (width) of a license plate, the length of the license plate can be determined since its width is proportional to its length. A new algorithm is presented in this paper to simultaneously perform the thresholding operation on the color and edge of the images obtained after proper preprocessing. Since the blue part of a license plate is near its left edge, the common features of the two obtained images are merged. The merged image is then used in Hough transform to detect the license plate. After detecting the license plate and according to the constant ratio of the width of each character to the length of the license plate, the location of each character is determined and the value of the character is recognized using a multilayer perceptron (MLP) neural network. Since this is a cascaded method, it can benefit from the advantages of other methods in different areas, such as color processing, edge detection, and morphological operations. Moreover, because most images are color images, the proposed method effectively uses color features, while this usage is less common in the literature. To evaluate the accuracy of the proposed method, some images are collected using a mobile phone camera or randomly from the Internet. A total of 288 images are used to assess the accuracy of the license plate detection, and 2200 images are used to measure the validity of the license plate character recognition. The accuracy of detecting license plates is 93.75% in this study.

Keywords: Car license plate detection; Color processing; Edge processing

1. Introduction

Nowadays, the world is moving toward mechanization. Everything can be done automatically because it is cheaper, less risky, and faster. License plate detection is one of the most important processes in an automatic license plate recognition system. By using license plate recognition, the presence or absence of taxi and bus drivers can be realized, the offending drivers can be identified and the law can be enforced, automatically. Moreover, the target vehicles can be tracked to prevent unauthorized persons from entering certain areas. Most license plate detection systems are designed for outdoor usage. However, license plate detection under variable environmental and climatic conditions is a challenging issue due to the changes in lighting, snow/fog,

day/night time, and problems with cameras. For instance, dust and camera shake can blur the image, which makes it difficult to detect the license plate and leads to wrong output. Therefore, license plate detection techniques are faced with complex challenges [1–6]. Although a deep learning solution can offer outstanding performance in terms of accuracy, it may not be efficient in terms of calculations and resource management. Therefore, a multi-step approach based on classical image processing techniques may offer acceptable performance at the expense of computational cost. In this study, a license plate detection system that includes preprocessing to reduce the number of calculations is proposed. This system improves image quality and simultaneously uses color processing and edge detection operation to detect, respectively, the blue part of the license plate and the

license plate itself. Morphological transformations are also used to increase the accuracy of edge detection. Then, this system merges the common features obtained from the two methods and uses the Hough transform to accurately detect the license plate.

The remainder of this paper is organized as follows: Section II reviews the related studies on license plate detection. Section III describes the proposed approach for license plate detection in detail. Section IV shows the evaluation and experimental results of the proposed method and its comparison with some of the previous methods. Finally, Section V concludes the paper.

2. Related works

In [7], Al-Shemarry and Li proposed a robust method for preprocessing enhancement of license plate detection from complex vehicle images. In this reference, a local binary pattern and median filter with a histogram of oriented gradient descriptors were used for license plate detection. License plate recognition in [8] was mainly focused on number plate localization and license plate recognition from an image in various areas. In this method, optical character recognition (OCR) was used to detect license plates. In [9], the location of the plate was approximated based on a complete analysis of the edge features of the plate. At last, a Bayesian classifier was used to exactly locate the license plate. In [10], a method was proposed for license plate detection and recognition of vehicles in Iran. This method included the characteristics of different resolution variant background colors and different font sizes. Moreover, this reference used the deep learning approach, which presented good accuracy and real-time efficiency. For this purpose, two YOLO v.3 deep networks were used. Xiao et al. [11] proposed a method for license plate detection in low-quality images based on color difference and used a support vector machine (SVM) recognition model with good efficiency. In [12], a method was used based on edge and color features for car license plate detection. In this work, two methods of image enhancement based on edge density were presented for preprocessing. In [13], Baohua et al. proposed a method for license plate detection based on histogram equalization under constant light conditions. In [14], a license plate detection approach was proposed based on vertical edges using a Sobel edge detector. This method worked well for low-contrast images, but it might not be suitable for complex backgrounds. In [4], Azam et al. proposed a license plate detection method based on filters and initial improvement techniques under bad weather conditions, such as fog. In [15], a method was presented for license plate detection based on wavelet transform and experimental studies. In this paper, histogram equalization is used to increase the detail of the plate edge in an image, but this method depends on the vertical and horizontal details of the characters. Tadic et al. [16] used a two-dimensional fuzzy Gabor filter for license plate detection. This method focuses on complex backgrounds and low-quality images. In [17], a learning-based single-image super-resolution method was proposed to detect low-quality license plates. This method used the former knowledge of the input with low-quality resolution.

In [18], Panahi and Gholampour proposed a method for the detection and recognition of dirty license plates. This method was intended for high-speed applications. In [19], a method was suggested based on multiple wavelet transform. This method used fuzzy logic and histogram equalization to improve images and was sensitive to images taken from different angles. In this study, color and edge features were used for license plate detection.

3. Proposed approach to license plate detection

In this section, we present a new cascade method for car license plate detection. Fig. 1 shows the flow of the proposed method. In the proposed method, considering that the license plate is installed in the lower part of the car, we first remove $\frac{1}{3}$ of the images in preprocessing. This reduces the information for subsequent processing. Then, four images corresponding to red, green, blue, and gray channels are extracted from the original color image.

In the next step, we use image enhancement methods to improve the quality of the grayscale image. Then, using color processing techniques and license plate features, the candidate license plate locations are identified. Because many of the identified areas do not include the license plate, some of these areas are removed by using a new OCR method. Therefore, because the license plate area is smaller than $\frac{1}{10}$ of the image, among the candidate areas for the blue part, those areas larger than $\frac{1}{10}$ of the image size are removed by setting a threshold. In the output image, there are usually discontinuities due to noise and possible damage, such as light radiation, which leads to poor results. Using the LDF method [20], these discontinuities and some false positive areas can be eliminated. The resulting image in this step

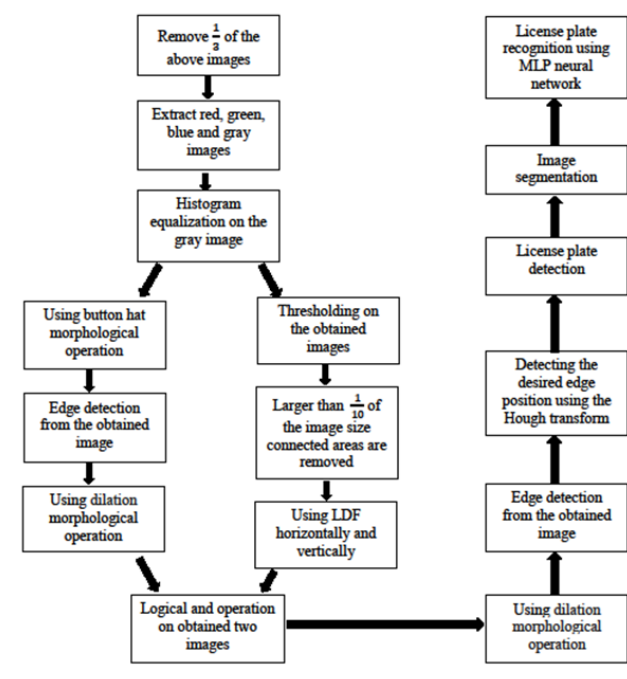


Figure 1. The flow of the proposed method.

is saved for later steps. In the next step, the bottom-hat transform is applied to the resulting grayscale image. Next, edge detection [21] and a morphological operation are applied to the image and the image is then saved. In the next step, we perform a bitwise AND operation for two resulting images, and possible discontinuities are eliminated by using a morphological dilation operation.

Subsequently, vertical edges are found using the edge detection method. The vertical edges of the license plate should be between -30 and +30 degrees. Therefore, these threshold values are used in the Hough transform, and the location of the vertical edge attached to the blue part of the license plate is found. After detecting the license plate, its characters are segmented, and finally, a multilayer perceptron (MLP) neural network is used to recognize the numbers on the license plate.

A. Preprocessing

In the preprocessing phase, the top $\frac{1}{3}$ of the taken image is removed to reduce the computational burden. This is because the license plate is in the lower part of the car and the top $\frac{1}{3}$ of the image has no license plate (see Fig. 2).

B. Extract color features

In this step, four images are extracted from the color image in the previous step. These images correspond to red, green, blue, and gray channels.

C. Grayscale image enhancement

Histogram equalization is performed on the grayscale image that was generated in the previous step. This operation enhances the grayscale image to help find the edge in the next steps. Figure 3 shows the results of steps B and C.



Figure 2. (a) The original image and (b) The image after removing the upper part.



Figure 3. Histogram equalization on (a) grayscale, (b) red, (c) green, and (d) blue images.

D. Color thresholding

In step D, the thresholding operation is performed on the four images obtained in the previous step. First, a binary image is created in which the value of each pixel can be either one (white) or zero (black). Subsequently, all pixels in the binary image become one, and then, the value of a pixel with one of the following characteristics becomes zero. These values are calculated according to the color of the blue part of the license plates in different light conditions.

- The value of the pixel in the red image is more than 0.4 of the maximum possible value.
- The value of the pixel in the green image is more than 0.9 of the maximum possible value.
- The value of the pixel in the blue image is less than 0.5 of the maximum possible value.
- The value of the pixel in the grayscale image is more than 0.8 of the maximum possible value.

By considering these threshold values, a binary image is obtained, which includes the blue part in proximity to the left edge of the license plate. Fig. 4 shows the image obtained in this step.

In many images that include license plates, there are other regions than the blue part. Moreover, there may be other blue objects, especially the car body, so our color detection algorithm may face some problems. However, these problems are resolved in the next steps. Fig. 5 shows an example of these images.

E. Using OCR

To avoid the problem of confusing blue regions, the OCR algorithm is used to determine the interconnected white areas in the previous step (see Fig. 6).

The desirable part of the license plate is smaller than $\frac{1}{10}$ of the image size. Therefore, based on thresholding, the connected areas that are larger than $\frac{1}{10}$ of the image size are removed as shown in Fig. 7.

F. Using line density filter

In step F, a line density filter (LDF) [20] is applied to the image. First, an LDF with a value of $t_{d_i} = 0.1$ is applied to the image obtained in the previous step. Therefore, the



Figure 4. (a) The original image and (b) The image after color thresholding.

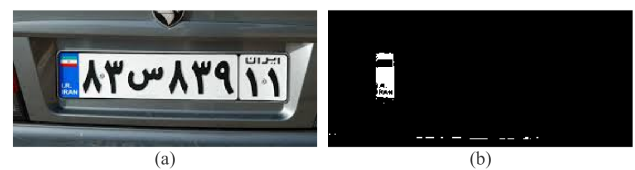


Figure 5. (a) The original image and (b) The image after color thresholding.



Figure 6. (a) Original image and (b) The image after color thresholding.

discontinuous horizontal lines in the image are connected. Next, the resulting image is rotated 90 degrees, and once again, an LDF filter with a value of $t_{d_i} = 0.5$ is applied to the image to connect the discontinuous vertical lines in the image. These two t_{d_i} values are calculated according to the best output results from the experiment. The resulting image is then rotated 270 degrees to reach the initial angle. This removes not only discontinuities but also some false areas that have been mistakenly considered as candidate license plate regions. Accordingly, the accuracy of the license plate detection process increases. Fig. 8 illustrate the output of this step. The resulting image is saved as “Image 1” to be used in the next steps.

G. Using bottom-hat transform

The morphological bottom-hat transformation is performed on the enhanced grayscale image obtained in step C. More accuracy is obtained from odd and symmetrical windows; therefore, the window for the bottom-hat transform includes an all-in-one 5×5 valued mask. Bottom-hat morphology increases the accuracy of edge detection. Fig. 9 shows this step.

H. Image edge detection

A Canny edge detection operation is applied to the output image of step G. Since the blue part of the license plate is located on the left side of the license plate, edge detection

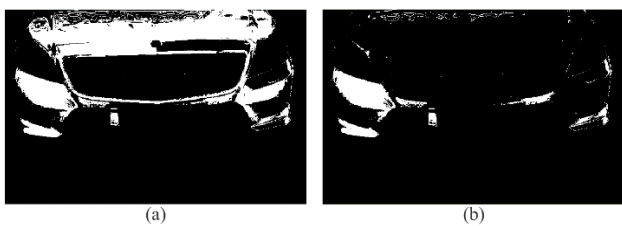


Figure 7. (a) The image after color thresholding and (b) The image after OCR thresholding.



Figure 8. (a) The output image of step E and (b) The image after applying LDF horizontally with $t_{d_i} = 0.1$ and vertically with $t_{d_i} = 0.5$.

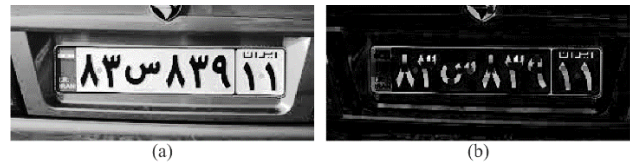


Figure 9. (a) The enhanced grayscale image obtained from step C and (b) The image after bottom-hat morphological operation.

operations can help to find the position of the part interest. This is not the case for many images, and the edge attached to the blue part of the license plate contains discontinuity. Discontinuity in the region of interest reduces accuracy. Therefore, in the next step, the discontinuity disappears. An example of these images is shown in Fig. 10.

I. Dilation morphological operation

Dilation morphological operation eliminates possible breaks in the image obtained in the previous step. Considering that it is important to detect the vertical edge of the plates in this algorithm an all-in-one window consisting of 10 rows and 2 columns is used to perform this operation. Fig. 11 shows the result of this step.

J. Logical AND operation

In this step, we perform logical AND operation on the binary images obtained in steps F and I; these images are saved as “Image 1” and “Image 2”. Because the region of interest including the blue part is attached to the edge, it must have both features together. In this step, the left edge of the license plate, which is attached to the blue part of

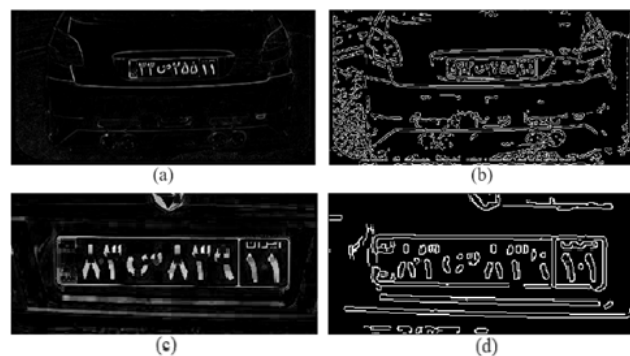


Figure 10. (a), (c) The images obtained in step G and (b), (d) The images after the Canny edge detection operation; the discontinuity can be seen on the left edge of the plate in (d).



Figure 11. (a) The image obtained in step H and (b) The image after the dilation morphological operation; as it is clear, the discontinuity on the left edge of the plate has disappeared.

the license plate, is identified. The resulting edge is usually accompanied by discontinuous and extra spots on the blue part of the plate, which must be removed in subsequent steps. Fig. 12 shows an output sample of this step in which the left edge of the plate has a discontinuity.

K. Dilation morphological operation

In the previous step, when two binary images are combined by logical AND, discontinuities may occur in the region of interest, so the dilation morphological operation is used. In this step, an all-in-one window consisting of ten rows and two columns is used. Figure 13 shows the result of this step.

L. Using Sobel vertical filter

The aim is to find the left edge of the plate, which is the region of interest. The left edge in this step is the place where the pixel values change from black to white. To find these points, the Sobel vertical filter is used. Fig. 14 illustrates the output of this step.

M. Using Hough transform

The lines obtained in the previous step are found using the Hough transform. Then, given that the desired line is the vertical edge of the plate, its angle should range from

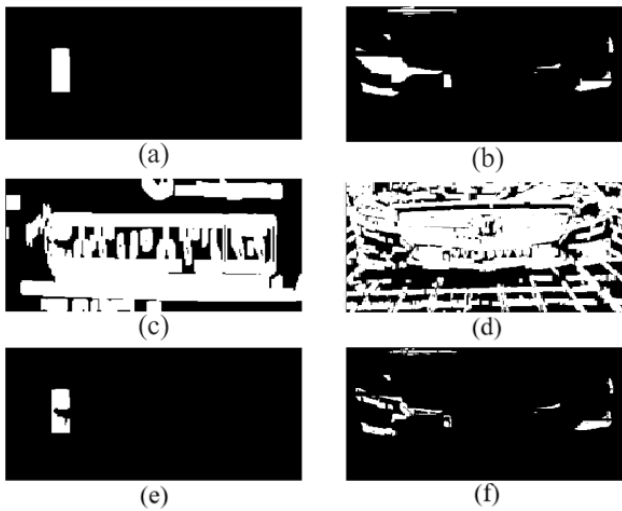


Figure 12. (a), (b) The output of step F (Image 1), (c), (d) The output of step I (Image 2), and (e), (f) the resulting image that is the logical combination of Images 1 and 2.



Figure 13. (a) The image obtained in step J and (b) The image after dilation morphological operation; it is clear that the discontinuity on the left edge of the plate has disappeared.

-30 ° to 30 °. Thus, by setting this threshold value, some of the obtained lines are eliminated. Finally, among the remaining lines, the largest one corresponds to the desired edge. Subsequently, the location of the license plate should be determined, followed by the elimination of the possible rotation of the license plate. Fig. 15 shows the output of this step.

N. License plate detection

An Iranian license plate is a rectangle with a length-to-width ratio of five to one. Depending on the length of the edge, and its angle, and using the dimensions of the plate, the exact location of the plate is detected. Fig. 16 illustrates the output of the proposed method for finding the location of the plate.

O. Image segmentation

It is necessary to segment the image of the license plate and extract its characters. The width of the blue part of an Iranian license plate is equal to 42% of its length. Therefore,



Figure 14. (a) The image obtained in step K and (b) The image after the edge detection operation.



Figure 15. Detected left edge, which is attached to the blue part of the license plate.

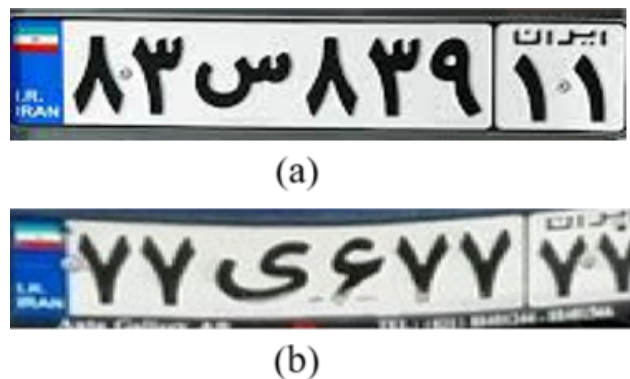


Figure 16. The result of the proposed method for license plate detection; the exact location of the license plate has been found.

after determining the length of the license plate, the blue part of the license plate can be ignored. The length of each numeric character is half the width of the license plate, and the length of the letter character is 0.8 of the width of the plate. In this way, license plate characters can be extracted. Seven numbers and one letter are extracted. Then, the resulting numbers and letters are binarized. A threshold is used to binarize the image, making the color of the characters white and the background black. Therefore, the values less than half of the maximum value become white (logic 1), whereas those more than half of the maximum value become black (logic 0).

P. License plate recognition using MLP neural network

The numbers and letters on the license plate can be read using a neural network. Two MLP neural networks are used, one to read the numbers and another one to read the letters on the license plate. Due to the difference in size and output of the numbers and letters on the license plate, two neural networks are used for recognition. To read the numbers and letters, first, they are resized. The size of a number is changed to 25×50 pixels, and that of a letter to 30×30 pixels. Then, the pixels are fully connected and enter the neural network. Two MLP neural networks with a hidden layer, consisting of 10 neurons with a sigmoid kernel, are used to read the numbers and letters on the license plate. Because numbers can be values between zero and nine, the output layer uses 10 neurons with a linear kernel to recognize them. A total of 1000 data samples are used to train this neural network. In fact, 70% of the data is used for training, 15% for testing, and the remaining 15% for validation. In this neural network, the performance is measured based on the mean squared error (MSE) criteria. In general, the MSE value of all data is 0.0382. On Iranian license plates, a letter out of 12 possible letters is used, so the output layer uses 12 neurons with a linear kernel to recognize the used letter. A total of 1200 data samples are used to train this neural network; 70% of the data is used for training, 15% for testing, and the remaining 15% for validation. In this neural network, the performance is measured based on the MSE criteria. In general, the MSE value of all data is 0.0286.

4. Experimental results

In general, some methods are cascaded to benefit from all of them together, so the accuracy reaches its maximum. Thus, in most image processing schemes, including in the present study, cascaded methods are used.

To evaluate the accuracy of the proposed method for license plate detection, the images of Iranian and non-Iranian cars with a blue region on the left side of their license plate are used.

The second part is license plate recognition. To check the accuracy of the proposed method in this step, the numbers and letters on only Iranian license plates are used. The method of collecting images in both steps is field-based, and the images are collected using a mobile phone or randomly from the Internet. This dataset contains images of a number of cars with different colors and in diverse light-

ing conditions and in different countries and diverse sizes, which are taken from varied angles, including the front and back of the cars.

An example of these images is shown in Fig. 17. The large variety of images in this dataset shows that this algorithm can perform well in different images. The images shown in Fig. 17 are taken from the Europlates¹ website, which is an important part of the dataset used in this article. To implement this method, MATLAB software is used. To increase the accuracy of the proposed method, different color threshold values are considered. Fig. 18 shows different color thresholds on grayscale, red, green, and blue images with the best values of 0.8, 0.4, 0.9, and 0.5, respectively. After testing different threshold values to find the best threshold value for OCR, $\frac{1}{10}$ is selected. The test results are shown in Fig. 19. In this paper, the bottom-hat transform is used to improve the accuracy. Fig. 20 shows different percentages of accuracy based on using bottom-hat transform

¹<https://www.europlates.eu/>



Figure 17. A number of images of the dataset.

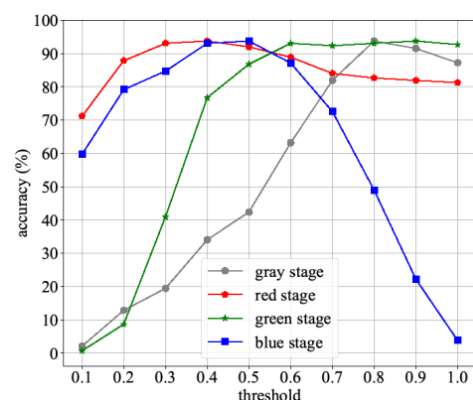


Figure 18. License plate detection accuracy by changing the color thresholds.

and top-hat transform or skipping this step. Additionally, to choose the best edge detection algorithm, the accuracy of the method is evaluated by using different edge detection algorithms.

It is found that the highest accuracy can be achieved by using the Canny edge detector. Fig. 21 shows the accuracy of different edge detection methods.

As mentioned, from the 288 collected images with license plates, the proposed method was able to identify 270 cases correctly and made mistakes in only 18 cases. Consequently, the accuracy of the proposed method to determine the location of license plates was 93.75% (Table 1).

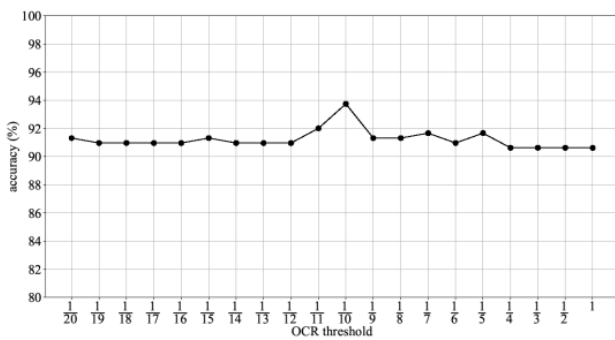


Figure 19. OCR threshold value to remove parts of the image.

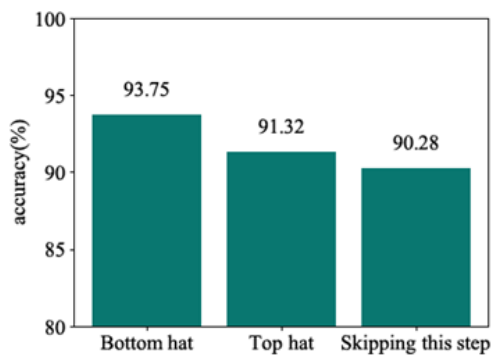


Figure 20. Using different methods in step G.

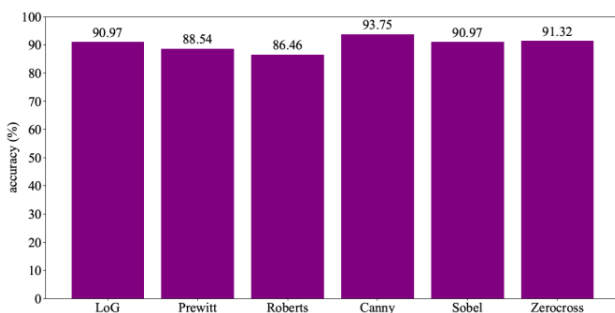


Figure 21. License plate detection accuracy of different edge detector algorithms.

Table 1. Performance comparison of different systems.

Reference	Performance
Present study	93.75%
[14]	91.4%
[10]	95.05%
[9]	98.31%
[8]	90%
[22]	92.10%
[23]	91.49%
[24]	83%
[25]	93.5%
[26]	90.61%

5. Conclusion

Some images with different dimensions and background colors were used to assess the accuracy of the proposed method for detecting license plates. Additionally, some rotated images were included among the collected images to ensure the accuracy of the proposed method. Among these images, there were also dirty plates, and the performance of our method was again satisfactory in this case. The ability of this algorithm is suitable for detecting license plates for Iranian cars and many other countries and is robust in change resolutions.

The proposed method was implemented in seven steps: 1) data preprocessing, 2) color processing, 3) edge detection, 4) combination of color and edge processing, 5) Hough transform for detecting the location of the license plate, 6) image segmentation, and 7) reading the characters on the license plate using the MLP artificial neural network.

This article presented a successful method for detecting license plates. Today, the use of cascade methods has been considered in most image-processing tasks and this research also used the cascade method. As mentioned, among the 288 collected images with license plates, the proposed method was able to identify 270 cases correctly and made mistakes in 18 cases, so the accuracy of this method to identify the location of license plates was 93.75%.

Acknowledgement

We would like to acknowledge, Islamic Azad University (Central Tehran Branch) for supporting the Extra-University Research Project with Saman Industrial Complex, entitled: *Feasibility and Conceptual Design of the Optimization of DOA and Localization Algorithms Using Artificial Intelligence Methods.*

Authors contributions

All authors contributed equally to prepare the paper.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interests

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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