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System for Automatic License Plate Recognition in Digital Image

Ana Lazović[1*], Mihailo Bjekić[1], Aleksandra Marjanović[2]
[1] PhD students at the School of Electrical Engineering, University of Belgrade, Belgrade, Serbia
[2.] School of Electrical Engineering, University of Belgrade, Belgrade, Serbia
[*] analazovic1995@gmail.com

Abstract: *In this paper, one of the realizations of an automatic number plate recognition (ANPR) systems is presented. The system is developed for the recognition of license plates issued in the Republic of Serbia. The system consists of several separate algorithms which overcome individual problems in ANPR. The problems discussed in this paper are license plate detection in the vehicle digital image, license plate skew correction, license plate segmentation and character recognition.*

Keywords: *license plate detection; binarization; radon transform; license plate segmentation; character recognition; skew.*

1. INTRODUCTION

Automatic number plate recognition (ANPR) is an important computer vision technique which encompasses recognition and identification of the objects in a digital image [1]. ANPR identifies characters in the digital image of the license plate in real time.

The system consists of four separate algorithms:

1. License plate localization and detection;
2. Skew license plate correction;
3. License plate segmentation;
4. Character recognition.

The input of the system is the digital image of the vehicle, whereas the output is an array of recognized characters. In the Fig. 1 the generalized block scheme of the ANPR is shown.

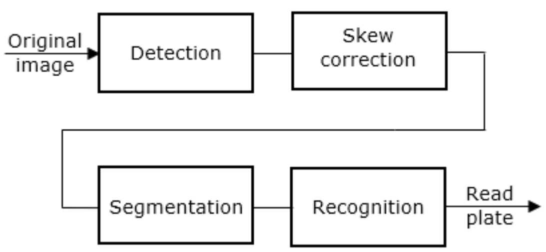

Figure 1. Simplified block scheme of the ANPR

The majority of papers, which consider ANPR, use digital images obtained using specialized high-quality cameras [2]. These cameras use specialized optics, infrared sensors, embedded systems as well as a preprocessing software, which significantly enhances the quality of the digital image. The obtained images have an optimal resolution and allow for an easy license plate recognition even when the targeted vehicles are moving at high speeds. In the contrast, the purpose of this paper is to develop an algorithm which successfully recognizes license plates in digital images of lower quality, obtained using commercial cameras and mobile phones.

In this paper, license plates issued in the Republic of Serbia, are considered. The system is developed using MATLAB and the Image processing toolbox.

For the purpose of testing the algorithm, the digital image database, consisting of 423 vehicle images, was created. The images were captured from different angles and distances from the vehicles, where the vehicles were stationary.

2. LICENSE PLATE DETECTION

License plate detection is the most important step in the process of ANPR. Success of the license plate detection directly determines the success of all following algorithms. If the plate is not detected successfully, the execution of the other algorithms is not possible.

During the development of the license plate detection algorithm, certain assumptions were made. The entire license plate must be visible and illuminated enough, without too many light distortions and any objects that cover any part of the license plate.

2.1. PREPROCESSING OF THE VEHICLE DIGITAL IMAGE

The goal of image preprocessing is to enhance the quality of the image and enable easier further analysis and processing. The quality of the used images varies and depends on the camera characteristics. Using a conventional camera, obtained images have certain defects, such as noise. Scene illumination also has a great influence on the quality of the digital image. Different photometric defects, such as shadow and reflection, may deteriorate the quality of the image and even make ANPR impossible. Digital image preprocessing consists of several steps: rescaling, converting RGB image into greyscale image, contrast enhancement and image filtering.

Dimensions of the input images varies in the range from 1875×2500 pixels to 3096×4128 pixels. Because license plate detection on higher resolution images has not shown better results, all images that are larger than the certain threshold are rescaled.

Because the processing of colored images demands higher computational power as well as being more complex, most of the license plate detection algorithms are developed to work on greyscale and binary images [3]. The original input vehicle digital image is converted into a greyscale image.

For the purpose of exposing finer details in the digital image, contrast is enhanced using the linear operation of contrast stretching, which increases the probability of success of the ANPR [4].

Finally, the digital image is filtered using the median filter with the goal to reduce noise. In the Fig. 2 an original vehicle image as well as the preprocessed image are shown.

Figure 2. Original vehicle image (left) and the result of the preprocessing algorithm (right)

By preprocessing the digital image, an image with smaller dimensions is obtained, which significantly reduces the time needed for execution of further steps of ANPR. Also, the quality of the image is enhanced which results in the increase of the probability of successful license plate detection.

2.2. BINARIZATION OF THE VEHICLE DIGITAL IMAGE

The image binarization is the most important step of the localization and detection of the license plate. Binarization reduces the complexity of data in the digital image and simplifies recognition and classification of objects in the image. Binarization method and threshold are very important for the license plate detection. In this paper, two different types of binarization methods are used. First type of binarization is the global binarization which uses the same threshold for the entire image. Global binarization is best suited for evenly illuminated images. One of the best known global binarization method is the Otsu method [3, 5], which is used in this paper.

In the case of uneven image illumination (reflection, shadow…), because the global binarization methods give unsatisfactory results, adaptive binarization methods must be used [6]. Unlike the global binarization, the adaptive binarization has a unique threshold for each pixel.

On the other hand, in the case of evenly illuminated images, adaptive binarization often gives worse results. The main problem of adaptive binarization lies in the fact that the license plate can be merged with other objects in the image. Because the system has to work with both evenly and unevenly illuminated images, no single binarization method can be used on its own, but rather a combination of both.

2.3. DIGITAL IMAGE REGION LOCALIZATION

The region in the digital image represents a set of connected pixels [3]. For the purpose of eliminating a certain number of objects, which are too small to represent a license plate, all regions of the binary image which have less connected pixels than the predetermined number, are discarded.

Because the license plate in the binarized image represents a connected region, all connected regions are potential candidates for the license plate. Firstly, all connected components (regions) in the digital image are labeled using a method in the MATLAB Image Processing Toolbox called Connected-Component Labeling. The labeled image enables separation of individual objects using their unique label. In the Fig. 3 all connected components are displayed on both original vehicle image and on the binarized image.

Figure 3. All found regions in the digital image on the original RGB image (left) and on the binarized image (right)

After labeling the image, specific characteristics of each connected component are determined (dimensions, position of the rectangle which encompasses the region, the center of the region, orientation, surface area, Euler number…).

As seen in Fig. 3, there are many regions that are potential candidates for the license plate. Each candidate must fulfill certain conditions concerning region characteristics.

Euler number represents an important feature of the digital image because it describes the topological structure of the image [7]. Euler number is invariant to different geometrical transformations such as scaling, translation, rotation and even certain nonlinear transformations which change the shape of the object. Because the license plate is a region on the binarized image which has a higher number of cavities (representing characters), the Euler number of the license plate is negative. Using the assumption that the region that is a candidate for the license must have an Euler number which is negative, many of the regions shown in Fig. 3 can be discarded. After discarding all regions with non-negative Euler number, the remaining regions are shown in Fig. 4.

Figure 4. Remaining regions after discarding regions with non-negative Euler number, original RGB image (left) and the binarized image (right)

The license plates have a standardized ratio between width and height, so this criterion is used in discarding all regions whose ratio is outside of the certain bounds. Because the license plate in the digital image can be at an angle, the bounds for the ratio must be chosen carefully. In this paper, it is adopted that the ratio must be between 1.4 and 6.

After discarding all regions with unsatisfactory ratio, the remaining three regions are shown in Fig. 5.

Figure 5. Candidates for the license plate shown in the RGB image (left) and the binarized image (right)

The result of the algorithm for region localization is a number of candidates for the license plate which satisfy the adopted criterions.

2.4. CANDIDATE SELECTION

For the purpose of selecting the right candidate for the license plate, further processing of all candidates must be done. The license plate has distinct edges which are a result of existence of dark characters on a white background. Based on the assumption that the license plate has the most vertical edges, compared to all potential candidates, vertical edge detection and its statistical analysis were used. To detect vertical edges in the digital image specialized filters were used.

Vertical edge detection was done using the Sobel filter [3]. In Fig. 6-8 the results of applying the Sobel filter on all three candidates is shown.

Figure 6. First candidate for the license plate (left) and detected vertical edges (right)

Figure 7. Second candidate for the license plate (left) and detected vertical edges (right)

Figure 8. Third candidate for the license plate (left) and detected vertical edges (right)

After acquiring the images with detected vertical edges, vertical image projection is done [8]. The results of the vertical image projection for all three candidates are given in Fig. 9-11.

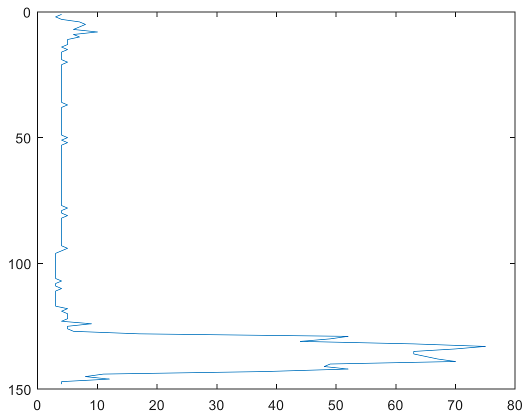

Figure 9. Vertical projection – first candidate

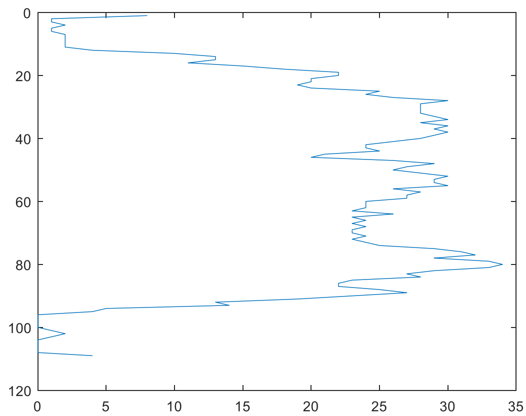

Figure 10. Vertical projection – second candidate

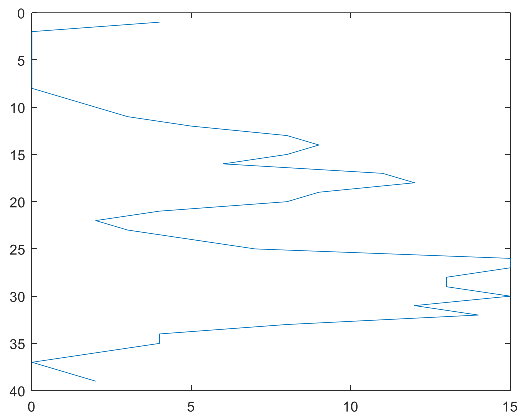

Figure 11. Vertical projection – third candidate

Analyzing Fig. 9-11, a specific shape of the vertical projection of the license plate can be observed. The vertical projection of the license plate has the maximum value in the middle of the projection while the values on both ends are much smaller. The reason for this shape of the vertical projection lies in the fact that the characters are in the center part of the license plate. The remaining two candidates have the vertical projection which is much different, and no specificity can be noticed.

The candidate for the license plate is chosen by calculating the mean of the vertical projection but discarding the starting and ending 25%. The candidate with the maximum mean value is declared the license plate.

Because of the previously determined dimensions and the position of the rectangle that surrounds the candidate, it is possible to segment the part of the original RGB image which represents the candidate. The result of the segmentation is shown in Fig. 12. The input of the algorithm for the license plate segmentation is an RGB image and not the binarized image for the reason that the quality of the candidate deteriorated during the process of license plate localization.

Figure 12. Detected license plate

3. CORRECTION OF THE SKEW OF THE LICENSE PLATE

Due to the fact that the vehicle digital image can be obtained from different angles, various distortions can occur. Depending on the position of the camera relative to the license plate, there are three types of tilt angles [9]:

1. Horizontal tilt (Fig. 13);
2. Vertical tilt (Fig. 14);
3. Combined tilt (Fig. 15).

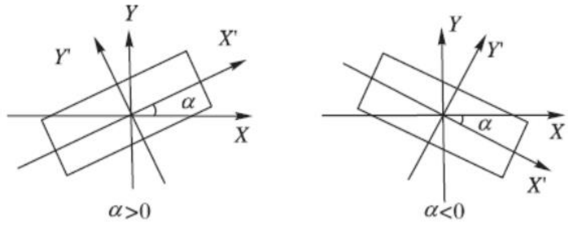

Figure 13. Horizontal license plate tilt [9]

In the Fig. 13 it can be seen that the horizontal tilt corresponds to the rotation of the license plate.

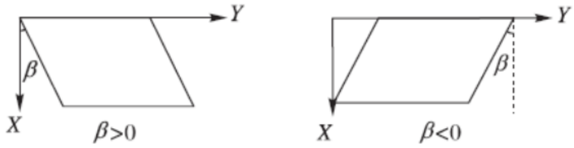

Figure 14. Vertical license plate tilt [9]

In the Fig. 14, it can be seen that the vertical tit corresponds to the shear of the license plate. Vertical tilt can be corrected by using the inverse affine transform [10].

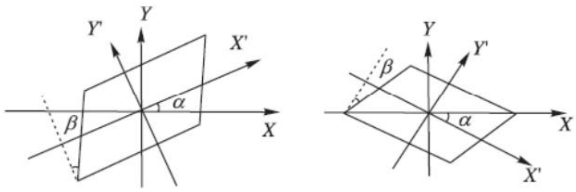

Figure 15. Combined license plate tilt [9]

In the Fig. 15, a combination of horizontal and vertical tilt is shown. Combined tilt is the most common type of license plate tilt.

In many cases, if tilt correction is not performed, problems in the succeeding algorithms may occur. One of the main problems is that the segmentation algorithm may not segment all characters in the license plate. If the license plate has either horizontal or vertical tilt, it is necessary to process the digital image of the license plate to eliminate the tilt. The skew correction can be divided into two steps.

The first step is the correction of the horizontal tilt, while the second step is the correction of the vertical tilt. For determining the angle of the horizontal tilt, Radon transform is used [11]. Before applying the Radon transform, all edges in the image must be detected. For the purpose of detecting the edges in the image, Canny filter is used [3]. The maximum of the Radon transform corresponds with the angle of the horizontal tilt. Block scheme of the horizontal tilt elimination is shown in Fig. 16.

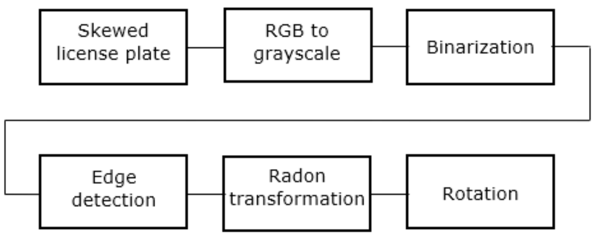

Figure 16. Horizontal tilt elimination block scheme

Because the orientation of individual characters is the same as the orientation of the entire license plate, the vertical tilt angle can be determined by determining the vertical tilt angle of individual characters. Most of the characters have the smallest width when there is no vertical tilt, as shown in the Fig. 17.

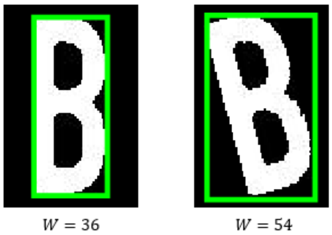

Figure 17. An example of width-tilt relation

For the purpose of correcting the vertical tilt angle, individual characters must first be segmented. After acquiring individual characters, each character is rotated in the range $[-30°, 30°]$, and its width is determined [12]. The angle for which the character has the minimum width is adopted for the angle of vertical tilt of the character. Based on the vertical tilt angles of individual characters, vertical tilt angle of the license plate is determined.

After acquiring the vertical tilt angle, the correction is done using the inverse affine transform.

4. License plate segmentation

After license plate detection, characters of the license plate must be segmented. Before the segmentation of individual characters, the license plate digital image must first be preprocessed. The preprocessing of the license plate image is rather similar to the preprocessing of the vehicle digital image and consists of the same steps plus determining the complement of the image. The result of the preprocessing of the license plate digital image is shown in Fig. 18.

Figure 18. Original license plate image (top) and the result of the preprocessing (bottom)

After preprocessing the license plate image, all connected components of the image are determined. The result of the algorithm is given in Fig. 19.

Figure 19. Connected region on the license plate

In Fig. 19 it can be seen that, aside from the regions that match the characters, additional regions were extracted. For the purpose of eliminating the additional regions, a criterion of expected height and width of the characters is used. Given the fact the character "0" is made out of two separate regions, the width of the expected region must be adopted small enough. On the other hand, the letter "I" has a much smaller width, so the criterion for width must be adopted small enough. If both height and width criterions are adopted small enough, other regions aside from the regions of characters would pass the criterion. In the end all regions whose width is not between 15 and 80 pixels and height not between 30 and 100 pixels, as well as those whose width is not between 5 and 50 pixels and height not between 50 and 100 pixels, are eliminated. After elimination of regions, the remaining regions are given in Fig. 20.

Figure 20. After elimination of the non-character regions

It can be seen that the character "0" consist of two separate regions, so the overlapping regions are merged. The result of merging the overlapping regions is shown in Fig. 21.

Figure 21. After merging overlapping regions

5. CHARACTER RECOGNITION

The last step in the ANPR algorithm is the character recognition. There are many different techniques when it comes to object recognition: statistical techniques, syntax techniques and soft-computing techniques. In this paper a statistical technique for object recognition is used.

In this paper, for the purpose of recognizing individual characters, template matching is used [13]. All characters that are supposed to be recognized are rescaled into the dimensions of the templates (57×28 pixels). For each character, the correlation coefficient with every template is calculated and the character is classified as the character on the template which has the highest correlation coefficient.

Because the license plates in Serbia have the starting two characters which are letters, as well as the last two, while in the middle there are ciphers, the first and last two characters are matched only with templates of letters while the characters in the middle are matched only with templates of ciphers.

6. THE PERFORMANCE OF THE SYSTEM

The success of each individual step of the ANPR affects the performance of the entire system. The success of the algorithms is determined using different criterions, such as a non-existent region (no region fulfills preset conditions), number of characters in the segmented license plate image (the number outside of the preset boundaries), etc. These criterions reduce the number of false positives in ANPR.

The greatest effect on the success of individual steps of the ANPR, has binarization. As it has been discussed in chapter 2.2, there are two types of binarization that can be used, whereas no single type of binarization can be used for all digital images. Because, in most cases, global binarization gives satisfactory results, as well as being less complex, each algorithm firstly uses global binarization. If the global binarization gives unsatisfactory results, then individual algorithms use adaptive binarization. The combination of global and adaptive binarization leads to longer duration of algorithm execution, while on the other hand, the performance of the ANPR increases.

The system was tested on a database with 423 vehicle digital images with different photometric characteristics and different license plate tilts. The performance of individual algorithms is given in Table 1, where performance is defined by the number of successful realizations of the algorithm compared to the total number of input digital images of the algorithm. The performance of the entire system is 93.14%.

Table 1. Performance of individual algorithms

	Performance [%]
Detection	95,50
Segmentation	98,51
Recognition	98,99

Mean execution time for the used database, when only global binarization is used, is 3.46 s. If only adaptive binarization is used, mean execution time is 11.87 s. The proposed system uses a combination of both global and adaptive binarization, resulting in the mean time of 6.74 s.

7. CONCLUSION

In this paper an ANPR algorithm, consisting of four separate algorithms, is implemented. The system enables for an automatic license plate detection and localization in the digital image, skew correction, license plate character segmentation as well as character recognition.

Special attention was paid to binarization step in detection and segmentation algorithm. Pros and cons of both global and adaptive binarization were presented. It has been determined that for the success of the ANPR, a combination of both types of binarization must be used.

The skew correction improves the performance of the entire ANPR algorithm by enabling character segmentation in the case of the license plate tilt.

The system was tested on a database of 423 different vehicle digital images. The performance of the entire system is 93.14%. Because of its high performance, the system can be utilized as a subsystem in electronic toll collection systems.

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