# Vehicle License Plate Detection and Recognition Using Symbol Analysis

Petr Cika, Martin Zukal, and Miroslav Sebela

***Abstract*—License plate detection and recognition is one of the most important aspects of applying computer techniques towards intelligent transportation systems. Detecting the accurate location of a license plate from a vehicle image is the most crucial step of a license plate detection system. This paper describes a proposing of a new region-based license plate detection method based on a symbol analysis. Throughout the detection and recognition the original image is filtered, transformed to gray-scale image and thresholded. In the next step the best candidates of regions are selected. The whole system was tested on fifty different cars with various license plates. The indication rate of success recognition is eighty eight percent.**

***Keywords*—detection, license plate, OCR, recognition**

## I. Introduction

LICENSE plate detection and recognition have a number of different applications relevant to transportation systems, such as detection of stolen vehicles, car park entrance or any statistical research. A number of methods was proposed, but only for particular cases and working under constraints. For example the rate of success is for the method proposed in [1] eighty six percent, in [2] ninety one percent, in [3] 92 ninety two percent. The mean rate of success in todays methods is about ninety percent.

A license plate recognition system mainly consists of three major parts; license plate detection, character segmentation and character recognition. Due to the diversity of parameters involved in car images, the first step, i.e. license plate detection, is the most crucial task among these steps. This paper describes a newly proposed method for detecting the license plates and recognition of license plate characters and numbers.

The remaining part of the paper is organized in the following order. The methods used in the proposed algorithm for license plate detection are described in section II, the methods for optical character recognition describes the section III. Final part of this paper consists of the proposed algorithm for vehicle license plate detection with experimental results. Section VI gives the conclusion.

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## II. Methods Used in the Proposed System

The proposed and tested system consists of more methods that depend on each other. The used methods are

- image enhancement,
- luminance transformation,
- thresholding,
- image segmentation into regions,
- evaluation of regions,
- optical character recognition,
- comparing recognized license plates with a database.

### A. Image Enhancement

The contrast of each input image with a car has to be adapted for better license plate detection. The contrast of any image can be improved by means of a contrast stretching method. The small difference of luminance levels around the license plate is a huge problem for detection algorithms. The difference is small in many cases because of car color or lightening conditions of the captured scene. The figure 1 shows a typical transformation used for contrast stretching.

Points $(r_1, s_1)$ and$(r_2, s_2)$ determine the shape of a function for the contrast stretching transform. Suppose that the points $r_1$ and $r_2$ define the minimum and the maximum brightness in the image. The values of the specific interval are normalized in the first step, so the $r \in < 0, 1 >$. The image stretching transform is performed by the equation

$$s = \frac{r - r_1}{r_2 - r_1}, \tag{1}$$

where $r$ is the current luminance level of the transformed coefficient and $s$ is the result after the contrast stretching transform [4]. This transform is suitable for the proposed algorithm because it is independent of any constant values and can be used for any image. The result of the contrast stretching transform shows the figure 2. The described transform is used in the proposed algorithm for license plate detection and recognition.

In case where the image was captured under very low lightening conditions, the previous transform is appropriate for use in combination with the histogram equalization. The equalization for the discrete histogram can be computed as summation. Each $k-$th luminance level $g_k$ is computed as

$$g(k) = \sum_{j=0}^{k} p(f_j) = \sum_{j=0}^{n_j} N = \frac{1}{N} \sum_{j=0}^{k} n_j, \tag{2}$$

where $N$ is the number of pixels in the image, $f_i$ is the luminance level and $n_j$ is the frequency of the luminance level [5].

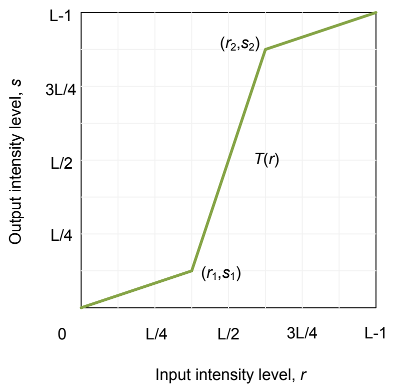


Fig. 1. Contrast stretching

(a) (b)

Fig. 2. Example of contrast stretching: (a) the original image; (b) image after contrast stretching.

### B. Luminance Transformation

The luminance part (gray-scale part) is suitable for the object detection in digital image. All the standard cameras and camcorders capture the video in the $RGB$ (Red, Green, Blue) color model. This model is unsuitable for image processing. In many cases, the image is transformed from $RGB$ into $YUV$ color model, where the $Y$ is the luminance part (gray-scale part) and $U$,$V$ are the chrominance part of the original image. Only the luminance part of the image is needed for the next process. To get the $Y$ part from the $RGB$ model the equation

$$Y = 0.299R + 0.587G + 0.114B \tag{3}$$

is used. Chrominance parts are unimportant for next processing.

### C. Thresholding

Thresholding is one of the main part used during image segmentation. It is used to transform the gray-scale image to binary image. A threshold level $T$ is set as first before the global thresholding. All the luminance points are compared with this level in the next step. If the pixel value is less than the threshold value $T$, the new value for this pixel is set to zero, otherwise to one. The image after the thresholding is called a *binary image*.

There exist more than one method for global thresholding, for example the iterative method [6], the Otsu's method [7] or the Simple Image Statistics (SIS) method [8]. Not only quality of recognition, but also the computational complexity are important in the process of vehicle license plate recognition. The vast majority of systems use this technique in real-time processing. For this reason the SIS thresholding method is advisable to use. This method automatically determines the threshold $T$ according to the following principle:

1) Two gradients (horizontal and vertical direction) are computed for each pixel in the image. Gradients are computed with equations

$$\nabla x = |f(x+1, y) - f(x-1, y)|, \tag{4}$$

$$\nabla y = |f(x, y+1) - f(x, y-1)|, \tag{5}$$

where $f(x+1, y)$ is a pixel adjacent to the current pixel from the right, $f(x-1, y)$ from the left, $f(x, y+1)$ from the bottom and $f(x, y-1)$ from the top.

2) The weight $\omega$ is set as maximum of two gradients $\nabla x$ and $\nabla y$.

3) The global weight rises up

$$\omega_{total} += \omega. \tag{6}$$

4) The total weight of current pixels is computed by means of equation

$$total += \omega_{total} f(x, y). \tag{7}$$

After all pixels of the image are checked, the final threshold value is computed as

$$T = \frac{total}{\omega_{total}}. \tag{8}$$

### D. Image Segmentation into Regions

Segmentation refers to the process of partitioning a digital image into multiple regions (segments). Pixels in the region are similar with respect to some characteristic or computed property, in the case of license plates to luminance level. The principle of a simple segmentation method is as follows:

- Single pixels are red in raster scan.
- Segments containing white pixes are searched.

If the pixel with the requested color is found, all neighborhood pixels are compared with each other. In case where the pixels have the same intensity, the object is detected. This process is repeated for the whole image. The main idea is to find a vehicle license plate. From the list of found objects only the objects with rectangular shape are selected. Each of these objects is tested for rectangle and oblong. The rectangle is circumscribed over the selected object in the first phase. The image is rotated from 0 to 90 degrees because the object inside the image can be rotated too. The minimum and maximum in $x-$ and $y-$ axises are detected in each angle of rotated image. The minimum distance in $x-$axis determines the object width and in $y-$axis the object height - figure 3.

If a shorter side of found rectangle is signed as $a$ and the longer side as $b$, then the aspect ratio (rectangle) is defined as

$$L = \frac{b}{a} \tag{9}$$

and oblong is defined as

$$R = \frac{N}{ab} \tag{10}$$

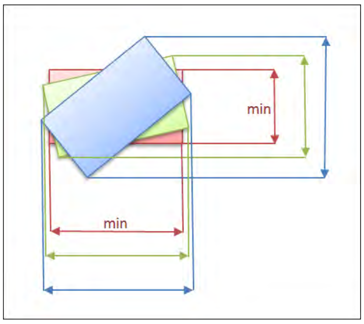


Fig. 3. Rectangle and oblong parameters

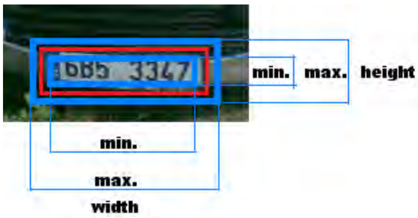


Fig. 4. Region selecting

A region is extracted from the image in case if the size equals to the specific aspect ratio. All the regions in the selected object that size is smaller or greater than the predefined symbol size are discarded. If the count of the rest symbols is between six and nine, the selected object declares the license plate - figure 4.

## III. Optical Character Recognition in Vehicle License Plate

The final step in vehicle license plate detection and recognition is reading of single characters and numbers. This step is very important for example at the entrance to car-park or for the police for stolen cars search. Single elements on license plate must be segmented and analyzed. The analysis is called as Optical Character Recognition (OCR) method. We chose from two variants:

- comparison with a predefined model,
- analysis of symbol region.

### A. Comparison with Predefined Model

The precondition of this method is an isolated character in license plate. The predefined model consists of images of possible characters and numbers `A-Z` and `0-9` (figure 5). Both images (predefined and recent) must have the same size. The predefined image is normalized to predefined size, the extracted symbol is then normalized to the same size. For the purpose of reading the license plate the image of size 100x100 pixels was selected (figure 6).

The symbol comparison starts after the normalization process is finished. The similarity of the compared symbols is determined by means of normalized cross correlation (NCC). The NCC is defined by the equation

$$NCC = \frac{\sum_{i=0}^{I-1} \sum_{j=0}^{J-1} O_{i,j} E_{i,j}}{\sum_{i=0}^{I-1} \sum_{j=0}^{J-1} {O_{i,j}}^2}, \tag{11}$$

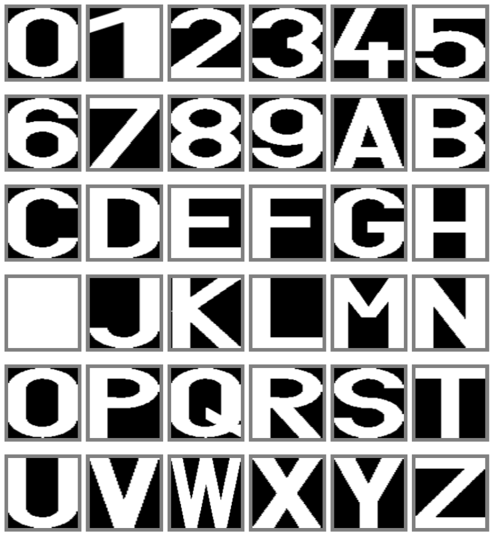

Fig. 5. Predefined normalized models

Fig. 6. Image normalization

where where $I, J$ define the size of the image with symbol and $O, E$ define the original and extracted symbol [9]. Thanks to NCC the most similar symbol is selected from predefined database.

### B. Analysis of Symbol Region

The main idea of analysis is dividing of the current symbol to sixteen regions. Each region should be compared with region of template in the same position, but this process is not effective. We propose a technique which uses characteristic vectors. The characteristic vector of white pixels was computed for each template and stored in the database. The database of white pixels was created and is used for comparison of analyzed symbol and symbol of database. All symbols must be normalized before analysis (figure 6). After the vector of white pixels is determined the vector distance for each template from database is computed by the equation

$$D = \sqrt{\sum_{i=0}^{N} (V_{Pi} - V_{Ai})}, \tag{12}$$

where $D$ is vector distance, $N$ is number of regions, $V_{Pi}$ is number of templates in region and $V_{Ai}$ is number of white pixels in the region of current analyzed symbol. The similarity of symbols can be determined as the minimum vector distance.

## IV. Proposed Method

We propose a method for license plate detection and recognition based on symbol region analysis. The proposed method uses preprocessing described in previous sections. The input image is improved by means of the contrast stretching method, then the luminance part is extracted and thresholded with

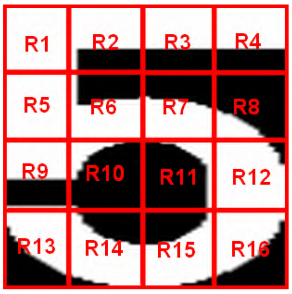


Fig. 7. Symbol regions


Fig. 8. An example of region evaluation

SIS method. The thresholded image is segmented into regions in the next step. For fast computation only the field where the license plate can be occurred is searched. This field is referred to as a *detection area*. The next tests are done only inside the detection area. The test whether the found region is rectangle and oblong and has defined aspect ratio is executed after the regions are selected. The strict aspect ratio can not be controlled. It is controlled whether the aspect ratio is in defined interval, as described in the figure 4. If the parameters of found and tested region correspond with parameters of the vehicle license plate, the region is extracted from the original image, transformed and filtered again. An example of extracted and utilized license plate region shows figure 8. Regions in this image that are smaller or greater than expectation size of symbols included in the license plate. Next, the number of regions can be computed. If this count is between six and nine, the region is marked as the license plate. The final step is based on the optical character recognition.

The whole method was proposed for the license plates in the Czech republic that have following formats ($C$ is a number and $Z$ is number):

- $CZC\ CC\ CC$
- $CZZ\ CC\ CC$
- $ZZZ\ CC\ CC$

There exists a problem with similarity of characters and numbers. The font used in license plates has for example the number zero similar to the character "O", etc. Our proposed method counts with the license plate formats described so the similarity of numbers and character can be only in defined positions. In this positions, all variants are checked. The variants are checked with predefined database. In case of congruency the license plate is marked as detected.

The proposed system is suitable for example for the car-parks. There is finite number of cars and the probability that there will be cars with similar license plate is not high.

The solution was tested on two video sequences. The first sequence was created from number of images (cars were captured from different angle), the second video sequence was captured in real world near an entrance to car park (cars were captured from the same angle). The total number of cars is fifty.

TABLE I
LICENSE PLATE RECOGNITION SUCCESS

| Number of license plates | Recognition failure | Recognition success | Probability of successfully recognition |
|---|---|---|---|
| 50 | 6 | 44 | 88 |

## V. CONCLUSION

This paper described the new proposed method for vehicle license plate detection and recognition. There was used many preprocessing algorithm for image enhancement described in section II. These methods were combined together and the robust system was proposed. The system is suitable for example for car-parks. The success rate of detection and recognition of license plate tested on 50 different cars was 88 percent. The testing parameters and results are described in the last section of this paper.

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