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Automatic License Plate Recognition System

Jakub Špaňhel*

Abstract
This paper aims at proposing an Automatic License Plate Recognition system (ALPR) from still images. This ALPR system is based on license plate detection by a cascade classifier and neural network (NN) license plate recognition. The system was developed in multiple iterations and different methods of license plate detection and character recognition were used for each of them. Comparison of the methods used is also presented. First of all, license plate location is estimated using cascade classifier. Secondly, individual characters are separated from the detected license plate. Finally, each of the separated characters is recognized using neural network. The system achieves an average precision rate of 88.94% for license plate detection, 83.81% for license plate recognition and has the an average success rate of 74.55% in total. This paper describes different solutions to license plate detection and recognition issues and compares some of the commonly used methods in this field.

Keywords: License plate detection — License plate recognition — Character segmentation — Character recognition — Intensity profiles — Neural network recognition — Cascade classifiers

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*xspanh02@stud.fit.vutbr.cz, *Faculty of Information Technology, Brno University of Technology*

1. Introduction

The Automatic License Plate Recognition (ALPR), License Plate Recognition (LPR), Number Plate Recognition (NPR) or Optical Character Recognition (OCR) systems are nowadays used in multiple applications. This paper proposes way, how to build a fast and efficient ALPR system using commonly known principles. The ALPR system described in this paper was created for use by the municipal police. Specifically, it was created to facilitate recording of traffic offences. Nowadays, it is used by the municipal police in some cities in the Czech Republic.

The problem of license plate recognition can be divided into several stages. The two main stages are license plate detection and license plate recognition. License plate recognition can be further divided into two sub-stages - segmentation of license plate characters and their recognition. However, it can also be solved in a single stage, too.

At least two different categories must be considered in the evaluation of any ALPR system - the success rate of license plate detection and license plate recognition.

The approach used in this paper is the three stage system. More precisely, the system is composed of the license plate detection by a cascade classifier, intensity profile based character segmentation and character recognition using neural network. For more details regarding this solution see Section 3.

The ALPR system proposed in this paper is in fact built using simple but very efficient solutions which

is evidenced by results in Section 4.2. The system is very easy to use because it was developed for non-user interaction usage. The compiled program can be run from a website as part of web-based information system and for single input file it gives single text result which can be passed to another part of information system.

2. Previous Studies

The LPR systems consist of two different categories - license plate detection and license plate recognition.

2.1 Vehicle License Plate Detection

First of all, we need to focus on license plate detection. Globally we can split license plate (LP) detection methods into two main categories. The methods from the first category are based on static image analysis such as color information, edges and other features, contour analysis, LP position, etc. The second category methods are based on machine learning solutions.

Some of these methods propose also license plate recognition instead of license plate detection only, as in article [1].

Static Image Analysis Methods

A static image analysis method based on color information and texture was introduced in article [2]. This method uses mathematical morphology and color information to estimate license plate location. Accurate location is determined from texture features.

On the other hand, article [1] proposes a robust license plate detection and recognition method based on contours analysis extracted from input image. The system is composed of detection and recognition stages. Detection is provided by candidate region extraction. After that, accurate location of license plate is determined using edge-based text detection.

Detection Methods Based on Machine Learning

A method from second category was introduced in article [3] and it is based on a two-stage AdaBoost method. The AdaBoost method used in this algorithm uses Haar-like features for computation and selection of license plate feature points. The AdaBoost algorithm is used to obtain region of interest image classification which is the result of the stronger classification. Experimental results of this method declare detection success rate of 98.38% at the average processing time ≈ 49 ms.

The AdaBoost algorithm is also used in the method which was described in article [4]. Instead of the first method, this one does not use Haar-like features, but a gradient image to estimate the license plate position. The license plate verification is done by a vote-based heuristic decision strategy.

2.2 Vehicle License Plate Recognition

Many different principles of license plate recognition are used nowadays. Optical Character Recognition (OCR) is the basic one which is used for printed text recognition. Methods presented here are more sophisticated and based primarily on classification.

Neural Network Based Methods

An automatic license plate recognition method was introduced in article [5]. This method uses 2-D Haar-like Discrete Wavelet Transformation (DWT) and artificial neural network for recognition. 2-D Haar-like DWT is used even twice. First, for extraction of low-frequency image parts only and then recognition is provided using sliding window over the detected license plate. Experimental results of this method declared a recognition success rate of 95.33%.

A hybrid technique for license plate recognition was introduced in article [6]. This technique uses wavelet transformation per feature points selection, followed by an artificial neural network classification.

Article [7] deals with Pulse Coupled Neural Network (PCNN) and template matching for license plate recognition. First PCNN computes the location of the license plate. After that, second PCNN is used for individual character extraction. When characters are extracted, template matching is used for recognition. This method has advantage in low light scene or with low quality images.

Image Classification for License Plate Recognition

Hierarchical classification is used in article [8]. At the first stage of recognition, optimal wavelet regions are used for decomposition and K-L transformation. After that, license plate recognition is provided using feature points extraction and hierarchical classification.

Article [9] describes license plate recognition algorithm based on Support Vector Machine (SVM). It is a three stage system, which is composed of preprocessing and license plate localization, individual character segmentation and their recognition.

3. ALPR System Components

The ALPR system proposed here is composed of three separable modules - license plate detection module, character segmentation module and individual character recognition module.

The solution of the presented ALPR system is very modular. Each module (stage of the system) can be replaced by another one, if it has the same interface.

It allows creating a new module for some specific situations of usage and also improving each module to get better results.

In the first stage of development, this system was composed of license plate detection by edge appearance and an approach based on local features. Also character recognition was based on template matching before neural network recognition was used. Results of comparison of these different approaches are described in Section 4.2.

3.1 License Plate Detection by Cascade Classifiers

License plate detection is the first key point of this ALPR system. As mentioned above, license plate detection was based on edge appearance and local features approach, i.e. Harris corner detection, Sobel operator; morphological operations and watershed algorithm were used to acquire license plate location in the image. This approach was acceptable only for certain kind of input images and it was replaced by detection by a cascade of classifiers.

Examples of input images are shown in Figure 1. Input image must be preprocessed for further use. Image preprocessing includes several basic operations such as image resize, grayscale conversion, histogram equalization, etc. After the input image preprocessing, it is passed to the cascade classifier to detect license plates.

The cascade of classifiers is a combination of several weaker classifiers into a strong classifier which is more accurate. License plate detection by cascade of classifiers used in this system is based on Local Binary Pattern features and Gentle Ada-Boost algorithm.

The result of cascade classifier detection is a set of rectangles considered as license plates. Because this system is being used by web-based information system on a server, the resulting set of rectangles is reduced to a single one with the biggest probability of license plate occurrence.

3.2 Character Segmentation Based on Intensity Profile

Character segmentation module was developed to ensure better character recognition. Character segmentation works on binarized detected license plate image where individual characters are separated using horizontal and vertical intensity profiles. In this case, the profile is a kind of an image histogram, where each histogram bin represents index of row/column of input image and its value is estimated by sum of pixel with zero intensity value.

Figure 1. Example of testing and real-user datasets. Pictures A and B are from testing dataset. Pictures C – F are taken by municipal police officers.

Intensity peaks, i.e. regions with the highest concentration of zero intensity in profile bins are searched from center of image to the borders. Minimum values are then searched from these peaks back to the center of the image. These minimum peaks are used as indexes to decrease region of interest of the image.

Similar system of character segmentation was proposed by Aggarwal [10] but this system exploits horizontal and vertical profile of edges instead of intensity profiles.

First of all, vertical profile of image rows is computed by equation (2) to estimate the top and the bottom edges of license plate characters. Horizontal profile of image columns is computed afterwards by equation (3) to estimate the left and the right edges of all characters. Both of these equations use the function of $countZeros(I)$ which returns the count of pixels with zero intensity, i.e. black pixels in a given matrix row/column $A_{i,j}$ of the input image. The $countZeros(I)$ function is described by equation (1).

$$countZeros(I) = \sum_{I:src(I)=0} 1 \quad (1)$$

$$VP[i] = countZeros(A_i) \quad (2)$$

$$HP[j] = countZeros(A_j) \quad (3)$$

Separation of each individual character of a license plate is also conducted by horizontal profiles where individual peaks are separated based on local minimum values. Example of an ideal input image and its intensity profiles is shown in figure 2.

3.3 Character Recognition Using Neural Network

Separated character recognition, as well as license plate recognition globally, is another key point of this ALPR system. Character recognition is now based on neural network recognition. Neural network used in

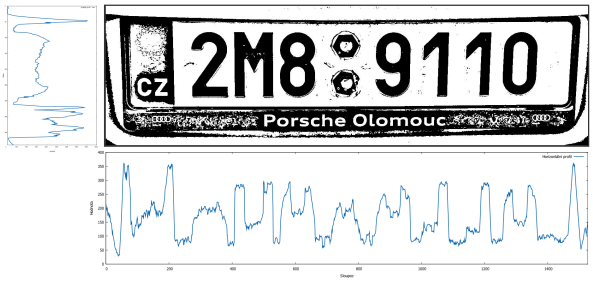

Figure 2. Example of an ideal input with the result of profilation. Vertical (left) and horizontal (bottom) profiles show the intensity of a specific license plate. One of each curves specifies vertical or horizontal intensity profile. The horizontal profile shows the precise separation of individual characters.

this paper is a three layer neural network which uses back-propagation algorithm for training and symmetrical sigmoid activation function.

Input layer consists of 160 nodes for input image resolution of 10×16 pixels and considers the grayscale value of each pixel. Other 40 nodes are in the hidden layer. The output layer consists of 32 nodes which represent the allowed license plate characters. An example of a neural network training dataset, as well as an example of the allowed characters is shown in Figure 3.

After the character segmentation, each segmented character is preprocessed and passed to the neural network for final recognition. The neural network returns the value and index of the best character for the input image.

Neural network solution replaces the original template matching method which was used in the first stage of the development. The template matching method is based on a set of license plate character templates. In some specific cases, the template matching method has better result than the neural network recognition, especially when there is not enough training data for some character. On the other hand, neural network recognition has a better result at the global scale.

4. Implementation And Experiments

4.1 Implementation

The ALPR system is implemented in the *C++* programming language and the *OpenCV* library is used. System is multiplatform because it was developed on Unix style operation system but it is used on the Windows Server.

Due to the deployment on the Windows Server, the executable file was built statically. It is really easy to use with web-based information system for which it

Figure 3. Example of character a dataset separated from input images. Characters G, O, Q, W are missing because they are not allowed to be used on the Czech Republic license plates.

was created.

4.2 Experimental Results

During development phase, three sets of input data were created. Two other datasets were created by real system users, i.e. the municipal police officers. These datasets are also included in experiments and their results. The size of the input datasets is shown in Table 1 and an example of testing and real-users dataset is depicted in Figure 1. An example of a recognized license plate on a part of the input image is shown in Figure 4.

Table 1. Description of testing image sets. Test data stands for dataset created in the development stage. Real data is the dataset from the real system users.

Input set	Number of images	Origin
Set 1	104	Test data
Set 2	52	Test data
Set 3	106	Test data
Set 4	148	Real data
Set 5	78	Real data

The evaluation and comparison of license plate detection method is shown in Table 2. Edge based detection method and cascade classifier detection was mentioned above, in Section 3.

Table 3 shows the evaluation and comparison of the license plate recognition method - recognition by template matching, neural network recognition with binarized information and neural network recognition using grayscale values.

Figure 4. Example of visualized system output. All pictures contain a part of the input image, detected license plate region and license plate text. Picture 2 and 9 represent license plate detection failure. Picture 3 shows bad recognition of the first character, which was classified as number 2 instead of Z character.

Table 2. Comparison of license plate detection methods

License plate detection methods		
Input set	Edge based method	Cascade classifier
Set 1	81.26%	90.55%
Set 2	86.67%	94.17%
Set 3	92.45%	96.34%
Set 4	56.32%	78.97%
Set 5	64.51%	84.38%
Average	76.24%	88.94%

Table 3. Comparison of character recognition methods.

Character recognition methods			
Input set	Template matching	Neural network Binary	Neural network Grayscale
Set 1	68.46%	75.43%	85.79%
Set 2	77.22%	83.14%	85.73%
Set 3	79.59%	88.84%	92.17%
Set 4	15.00%	45.00%	74.33%
Set 5	25.00%	61.24%	81.05%
Average	53.06%	70.73%	83.81%

Table 4. Results of license plate detection and recognition in total. Detection based on cascade classifier and license plate recognition by neural network with grayscale information.

Results of detection and recognition			
Input set	Detection	Recognition	Total success rate
Set 1	90.85%	85.79%	77.94%
Set 2	94.17%	85.73%	80.73%
Set 3	96.34%	92.17%	88.79%
Set 4	78.97%	74.33%	58.70%
Set 5	84.38%	81.05%	68.39%
Average	88.94%	83.81%	74.55%

To sum up, an average detection precision rate is 88.94%, an average recognition precision rate is 83.81%, therefore average precision rate in total is 74.55%. Results are shown in Table 4.

5. Conclusions

Automatic License Plate Recognition system proposed in this paper consists of three modules: license plate detection by cascade classifier, character segmentation based on the intensity profile and character recognition module using neural network. The system was developed for web-based information system usage and it is really easy to use. This paper gives a summary and comparison of the methods used for detection and character recognition at each stage of system development.

The final version of the ALPR has 88.94% detection success rate and 83.81% license plate recognition success rate now.

The problem of license plate detection as well as license plate recognition can be solved separately but both are needed to create an Automatic License Plate Recognition system. The use of machine learning algorithms can result in a fully functional system assuming a sufficiently large dataset and good settings. Recognition of individual separated characters is better than the whole license plate recognition, in specific cases, but good resolution and quality of input image is needed.

This study was the very first step to vehicle re-identification system which I am working on as my master thesis. The idea of this system is that we do not need character segmentation anymore, and therefore the license plate recognition is possible for low resolution input images and also that the system is invariant to projective and perspective transformations of input license plates. The license plate recognition is based on sliding window and neural network classification. The development of this vehicle re-identification system is already in progress and the system will be available very soon.

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