Robust Number Plate Detector Based on Stroke Width Transform and Neural Network

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***Abstract*— The number plate detection is a key step affecting the overall performance of the number plate recognition system. In the paper a novel algorithm for this purpose is proposed. The approach is based on the detection of text areas using the stroke width transform. More plate candidates are detected using the specifically developed image preprocessing scheme based on set of morphological operators and contour analysis. The final number plate candidates are properly classified using the neural network which is learned from the training dataset. Experiment results indicate on the high performance of the developed methodology.**

Keywords—automatic number plate recognition (ANPR); stroke width transform; contour detection, neural network.

I. Introduction

Intelligent transportation systems have a number of different applications including the traffic control, car navigation, security systems, parking guidance and many more. The automatic number plate recognition system (ANPR) is one of the most popular directions. The key idea of such system is to perform the extraction of the license plate area from the input image of video stream with subsequent segmentation of the symbols and optical character recognition [1]. The trick is that the processing can be made automatically using the computer vision methods. ANPR can be utilized in parking systems, tracking of the offenders in the road, the vehicle speed estimation, security control of restricted areas, border crossings, etc.

The detection of the number plate area is the most important part of the ANPR system [1]-[3]. Obviously, that the low accuracy of this step will lead to the performance degradation of the whole system.

The main challenges of the number plate detection are related with changing of the illumination level, visualization geometry and nonstationary backgrounds. In addition, the colors and sizes of number plates can be different as well.

A lot of different ANPR algorithms have been developed so far. The differences between existing methods are related with a type of features which are used for the number plate extraction. For instance, extracted image features can include shape, aspect ratio, color, spatial frequency, variance intensity, texture, etc. [1]. Some approaches utilize the edge detection techniques [1]-[2]. Efficient method based on the color edge detection [3] is proven to be efficient as well. Also it was shown that Hough transform can be applied for the number plate detection problem [4]. However, this approach is time-consuming and can not be applied in real-time.

Connected component analysis (CCA) is also a popular tool for the analysis of binary images. According to this approach, the binary image is scanned and the pixel connectivity is analyzed. Based on special properties of the plate area regions, the number plate can be extracted for the image [5]. More detailed review of the state-of-the art number plate detection methods can be found in [1].

In the paper a novel method for the number plate detection is proposed. At the first stage, the stroke width transform (SWT) [6] is applied for the location of the text candidate areas. At the same time specifically developed image preprocessing steps are applied for the extraction of another group of number plate candidates. The combined list of the number plate candidates is used as an input for the classification basod on the trained neural network (NN).

The developed hybrid approach can successfully handle various illumination scenarios, backgrounds and frame orientations.

In Section II the basic ideas of the text detection using SWT are described. Also a scheme of image preprocessing for efficient detection of number plate candidates areas is proposed. In Section III the final number plate extraction step based on the NN is described. Experimental results are illustrated as well.

II. Detection of Number Plate Candidates

A. *Principles of Stroke Width Transform*

The text detection in natural scenes is a challenging task. Various imaging conditions, different backgrounds and possible occlusions make a detection problem more difficult. In the paper we are interested in the location of the number plate in the vehicle image.

The SWT is a local image operator. The key idea of this operator is to calculate the so-called “stroke width” for each pixel of the input image. Thus, the resulting image will contain the widths of the strokes associated with corresponding pixels.

The principle of SWT calculation is the following. At first, the edge map using the Canny edge detector [7] is obtained. After that the gradient direction at each pixel is calculated. A good option is the usage of well-known Sobel derivatives [8]-[9] for this purpose. Such derivatives are determined as follows (3*3 window size example)

$$G_x^{Sobel} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix},\ G_y^{Sobel} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}. \qquad (1)$$

Here G_x^{Sobel}, G_y^{Sobel} are horizontal and vertical gradients respectively which are calculated as a convolution of the input image with described kernels (1).

After described preparation step the SWT can be performed. The gradient direction d_p for each edge pixel from the Canny edge image is considered. We follow the ray $r = p + nd_p$ until the edge pixel q is not found (Fig. 1).

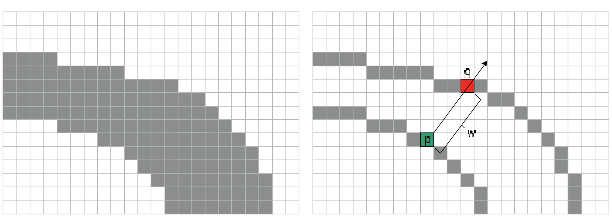

Figure 1. Principle of stroke width calculation

If the d_q is roughly opposite, each pixel of output image with stroke widths along the direction along the segment $[p,q]$ is assigned to the width $|\vec{pq}|$.

Fig. 2 illustrates introduced preparation steps and SWT calculation. One can observe the areas of equal stroke width in Fig. 2c. The next task is to combine such areas which will result in the list of the letter candidates. In order to do this several filtering rules are developed. At first, the connected component analysis is performed. The pixels with equal stroke widths (stroke width ratio threshold is used) are combined into the letter candidates. After that the letters can be extracted from the full list of connected components based on the stroke width variances within each connected component, the limitation of the aspect ratios and maximum acceptable height of the component. Remaining connected components are considered as letter candidates and used for the further detection of the words.

The final step of text detection chain is to combine the letters candidates into words. The text line should have similarities of stroke width, letter sizes and spacing. In addition, the color and orientation are utilized as well.

As a result, the sequence of number plate candidates is extracted from the input image. In the next section we describe another approach which can additionally improve the detection capability of the regions of interest.

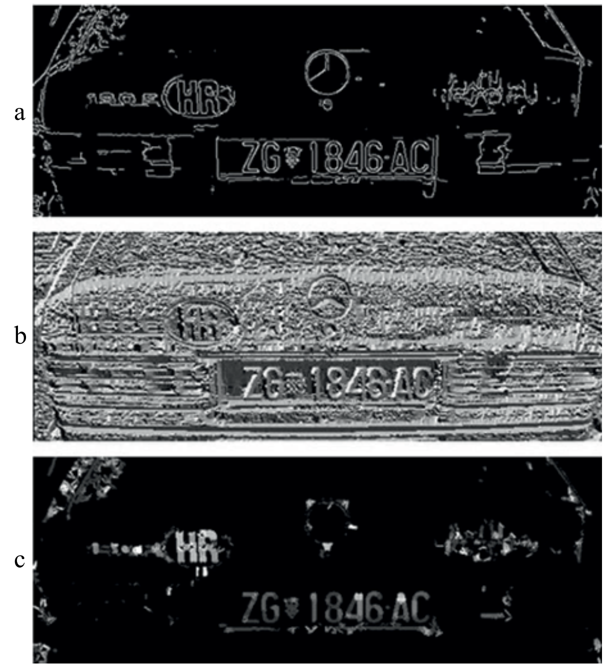

Figure 2. Illustration of text regions detection (a – Canny edge map, b – gradient directions, c – stroke widths)

B. *Image Preprocessing and Blobs Extraction*

In order to increase the final detection rate, we propose to use an alternative scheme for the location of the number plate area.

It is known that one of the options for the number plate detection is application of CCA for the binary image. Before application of this technique, we propose to apply several image preprocessing steps.

After the application of median blur, the morphological gradient is calculated. The morphological gradient is determined as a difference between the eroded and dilated images [8]. This operator has it highest values when the image intensity is changing most rapidly [8]. In particular, such areas correspond to the number plate borders.

An example of calculated morphological gradient is shown in Fig. 3a. The convolution of this image with a uniform box filer allows to increase the contrast (Fig. 3b).

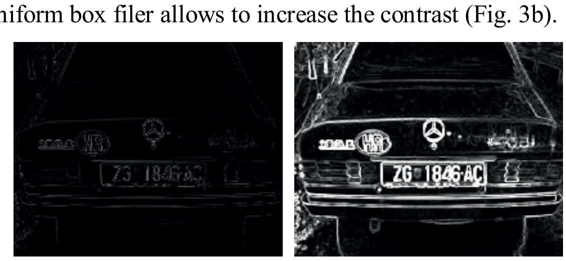

Figure 3. Application of convolutional operator.

After the image binarization [8], the conventional contour detector [10] is applied. Obtained contours can be filtered with respect to the area and the aspect ratio of the corresponding contour bounding rectangles.

An example of extracted blobs (filled contours) and corresponding bounding rectangles in the input image is given in Fig. 4.

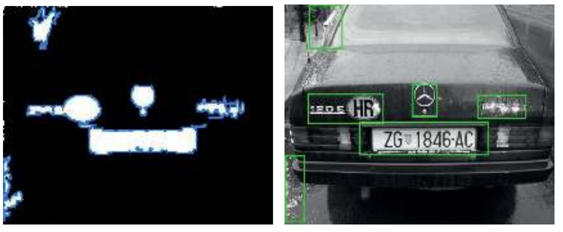

Figure 4. Ilustration of alternative preprocessing scheme.

The detected number plate candidates based on the developed alternative scheme are saved for the further analysis.

After the separate application of SWT for the text detection and described blob extraction algorithm, the final number plate candidates are found. The block-scheme in Fig. 5 contains the main steps of the described procedures.

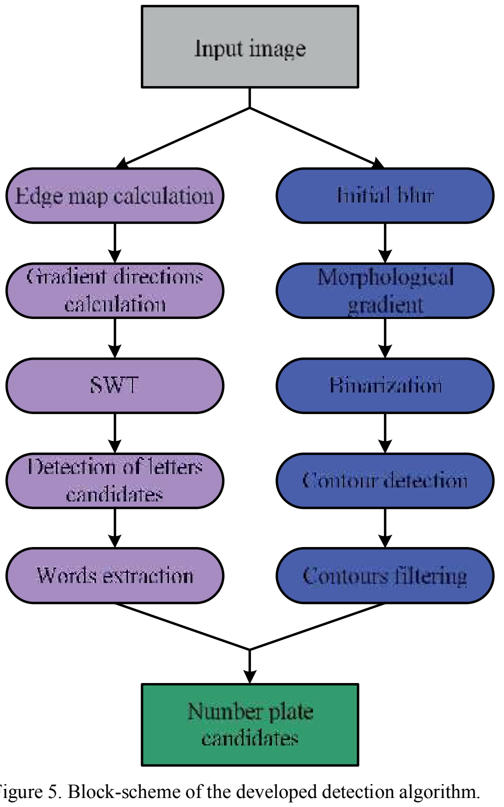

Figure 5. Block-scheme of the developed detection algorithm.

After the calculation of the SWT of the input image based on the Canny edges map and gradient directions, the letter candidates are extracted. Analysis of filtered letter candidates results in detection of words regions. This is the output of SWT analysis part. At the same time the proposed image preprocessing scheme is applied. For the suppression of the high-frequency noise, the median blur is applied. The image binarization is performed for the calculated image morphological gradient. Application of the contour detector with subsequent filtering of the contour areas and aspect ratio results in the list of number plate candidate areas.

The final list of candidates now can be used for the analysis and determination of the true number plate area. In the next section we describe how this is achieved using the trained neural network

III. Filtering of Plate Candidates And Experimental Results

Described hybrid approach returns the list of the number plate candidates. The last and the most important step is to determine the true plate image among the extracted list. Prepared training dataset of vehicle images is used for the evaluation of the number plate candidates. Fig. 6 illustrates the part of arbitrary taken images from the training dataset.

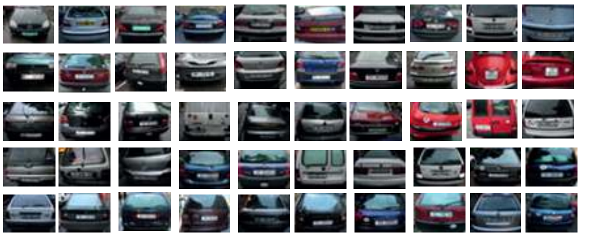

Figure 6. Example of part of training dataset.

The training dataset contains vehicle images with different aspect rations, various skewness level and imaging geometry. We have developed a classifier based on 3-layer perceptron neural network (NN). In order to efficiently train the classifier, the feature extraction [12] should be performed.

In general, two types of features can be used for the training of the neural network. For the local features one can use the sample statistical moments of the image and Haar-like features [13]. Another option is to treat the whole images as features. This can be done using the principal component analysis (PCA) [11]. At the first step of PCA each number plate candidate image is considered as a high-dimension data point. Based on the existing training set of images, the input feature matrix is considered

$$X_{ij}, i = 1..N, j = 1..Nd ,$$

where N is the number of images in the training dataset, Nd is the length of the column-vectorized images. According to the PCA, the data matrix is transformed to another basis, which contains so-called principal components. The variance of such components corresponds to the eigen values of the sample covariance matrix [11]. The number of extracted feature corresponds to the number of retained principal components. It is often the most of the variance is concentrated in only few PCs and this is used for the data compression. After such manipulation the extracted feature matrix is used as input for the NN.

We have tested the classification results for both local and global features. Each image in the test dataset was processed by the developed hybrid approach. After that each of extracted number plate candidates was properly classified using the learned NN.

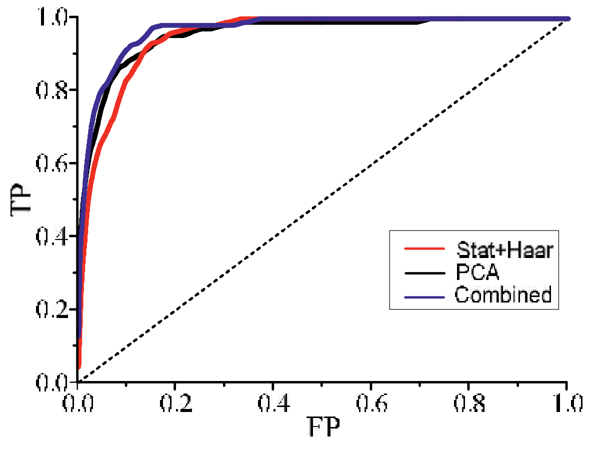

Figure 7. Calculated ROC curves.

One of the most commonly used instruments for the description of classification performance is receiver operating characteristics (ROC). It represents the dependence of true positive rate (TP) on the false positive rate (FP) [14]. Fig. 7 illustrates the ROC curve obtained for 3 different learning scenarios. One can see that the usage of PCA features leads to better classification accuracy than for the introduced local features. The best classification results are obtained for the case of usage of combined features set. The current detection rate is about 92%, the false detection is about 8%. Given experimental results indicate on a high performance of the developed hybrid procedure for the automatical number plate detection, however the algorithm still requires the improvements in order to minimize the false detection rate. In the future we are planning to develop the procedure for the estimation of image lightness in order to adapt the detection algorithm for significantly varying lightning conditions. Secondly, additional feature analysis will be incorporated in order to learn the NN more efficiently.

IV. CONCLUSION

In the paper, the algorithm for the automatical number plate detection is proposed. The approach is based on the analysis of the stroke widths for the extraction of text areas from the vehicle images. At the same time, the number plate candidates are extracted using the proposed blob analysis procedure. As a result, more consistent extraction of the number plate candidates is performed. The final location of required number plate area is determined using the neural network learned from the prepared training dataset. The approach successfully handles different imaging scenarios and can be applied in various intelligent transportation systems.

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