License Plate Recognition System

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Abstract

This paper presents a novel method of identifying and recognizing license plates, required by an automatic vehicle identification system. The main challenge was the isolation of the car's license plate, from the digital image acquired by the video system, under different illumination conditions and various angles. Thus, we have established the required preprocessing operations leading to successful plate identification. The string recognition stage is straightforward, after the completion of the character extraction process. Tested on Romanian plate images, the system performance was 93% of correct identified plates and 88.57% of correct recognized characters. Suggestion for further improvements are presented, as well as further related project developpment.

1. Introduction

Car's license plate detection and recognition became an interesting task just from the beginning of automation by the means of computer vision. By simply enouncing, one can imagine a wide range of applications, starting from parking access to vehicle management, as well as traffic control and public security. Being already subject to comercial many applications, license plate recognition systems continued to be an interesting topic for researchers. In all cases mentioned above, one will deal with a series of problems, mainly consisting of: requirement for real time processing; various illumination conditions; inclined plates; in motion vehicles; and plates belonging to other states.

An exhaustive study of license plate recognition is provided by Shridhar et al. [1], concluding that fusion of gray scale morphology and homomorphic processing are yielding to high rates of string extraction and recognition. In [2] a solution to the problem of fast passing vehicles and image blurring is given. Variable image acquisition angles give rotated characters in license identification strings. Such alterations are handled using the Hotelling transform in [3] or by the invariant properties of the normalized moment of inertia [4]. Recognition is generally achieved by template matching, neural networks [5] [6] [7], or other classifiers such as holographic nearest-neighbor [4].

In this paper, we report a simple method for detecting the license plate form a grayscale image and recognize the string contained by the plate. We first use a preprocessing stage, consisting of a certain number of transforms established heuristically for this specific type of images. The plate rectangle is then detected, using the Hough transform for locating lines and a template for the expected rectangular form. After appropriate character segmentation, the recognition stage is based on a template matching method.

2. Preprocessing

The preprocessing stage is generally required for further high level image processing algorithms and reduces the information quantities. We have employed the following preprocessing scheme:

- edge detection with a Prewitt operator
- low-pass filtering for noise cleaning
- thresholding with the Maximum Entropy Criterion

The use of Prewitt edge detection operator was motivated by his high potential of detecting horizontal and vertical lines, basically required for the rectangle shape of the plate. The resulting image is then low-pass filtered for noise removal and smoothing. The filter used here is a special case of the following parametric filter:

$$H = \left[\frac{1}{b+2}\right]^2 \begin{bmatrix} 1 & b & 1 \\ b & b^2 & b \\ 1 & b & 1 \end{bmatrix} \qquad (1)$$

a) b)

Figure 1. The Maximum Entropy Criterion thresholding. a) original image; b) thresholded image.

The Maximum Entropy Criterion [8], provides an unsupervised solution to the choice of threshold dilemma. Consider *f(x,y)*, an image of *NxN* pixels and *m* gray levels. Assume $G_m=\{0,1,...,(m-1)\}$ the gray levels and $f_i \in G_m$ the appearance frequency of the gray levels in image *f*. The probability of level *i* in image *f*, will be:

$$p_i = \frac{f_i}{N \times N}, i \in G_m \quad (2)$$

Thus, we obtain the $\{p_i \mid i \in G_m\}$ distribution. For a given *s* gray level, if $0 < \sum_{i=0}^{s-1} p_i < 1$, the next two distributions may be derived from this one, after a normalisation:

$$A = \left\{ \frac{p_0}{P(s)}, \frac{p_1}{P(s)}, ..., \frac{p_{s-1}}{P(s)} \right\}$$
$$B = \left\{ \frac{p_s}{1-P(s)}, \frac{p_{s+1}}{1-P(s)}, ..., \frac{p_{m-1}}{1-P(s)} \right\} \quad (3)$$

where $P(s) = \sum_{i=0}^{s-1} p_i$ is the total probability till (*s-1*) gray level.

The basic idea of the MEC method is the appropriate choice of threshold, that maximize the amount of information obtained from the object and background. Recalling that the measure of information is the entropy, the total amount of information given by *A* and *B* is:

$$TE(s) = E_A(s) + E_B(s) = -\sum_{i=0}^{s-1} \left(\frac{p_i}{P(s)} \right) \ln \left(\frac{p_i}{P(s)} \right)$$
$$= -\sum_{i=s}^{m-1} \left(\frac{p_i}{1-P(s)} \right) \ln \left(\frac{p_i}{1-P(s)} \right) \quad (4)$$
$$= \ln[P(s)(1-P(s))] - \frac{H(s)}{P(s)} - \frac{H'(s)}{1-P(s)}$$

where:

$$P(s) = \sum_{i=0}^{s-1} p_i \; H(s) = -\sum_{i=0}^{s-1} p_i \cdot \ln(p_i) H'(s)$$
$$= -\sum_{i=s}^{m-1} p_i \cdot \ln(p_i) \quad (5)$$

The Maximum Entropy Criterion assumes finding the threshold *s'* that maximize the following measure:

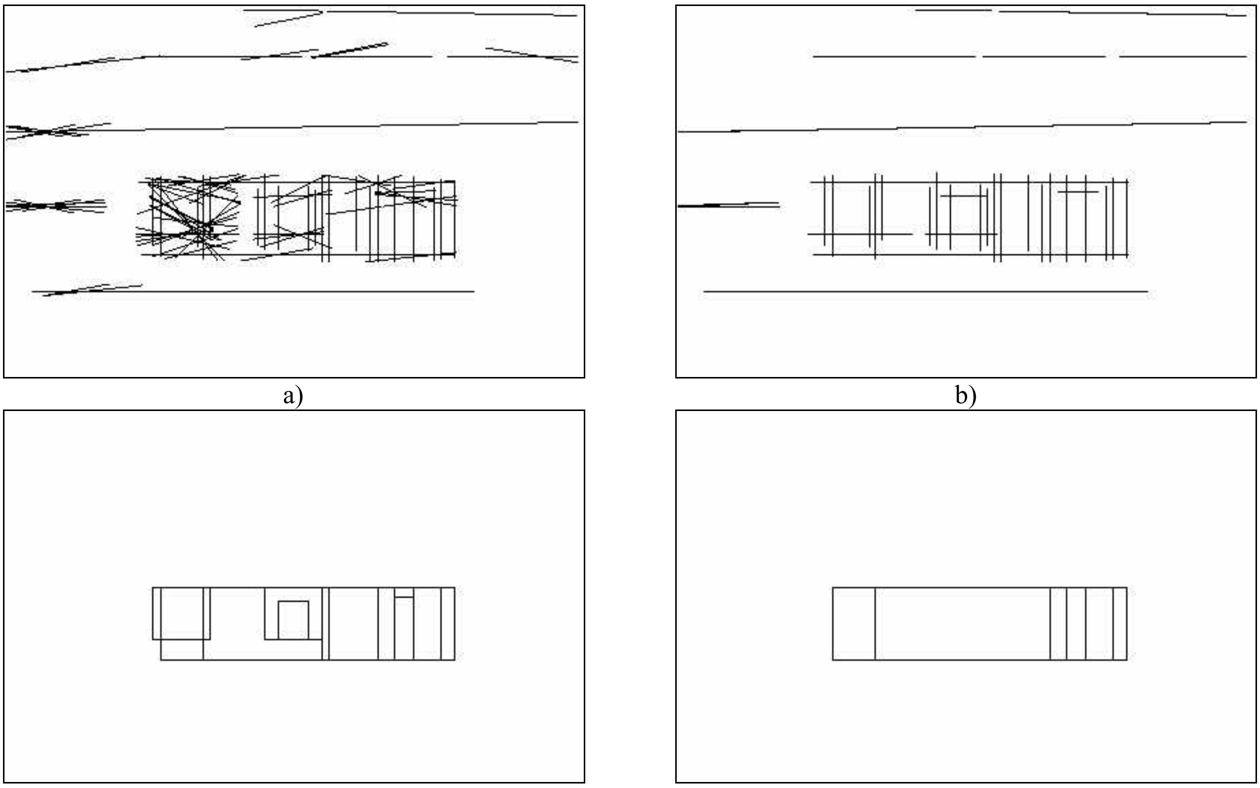
$$TE(s') = \max_{s \in G_m} TE(s) \quad (6)$$

The method is computationally feasible and leads in short time to the solution. Also, thresholds are determined automatically. Figure 1 shows the original image and the thresholded one, at the end of the preprocessing stage.

3. License Plate Detection

License plate detection stage in based on the Hough transform and was used in [9]. The main motivation for using this technique was the rectangle shape of the plate and the possibility to emphasize it by preprocessing.

Detection uses the following steps:
1. Hough transform of the thresholded image. We have employed the classical Hough transform. The sets of thresholds required by the transform were established upon the informations observed from the images.
2. Detection of peak values above some threshold, using the polar coordinate image resulted from transform. By inverse transformation from the Hough space, obtain the euclidian coordinates of the lines and insert them in a previously created list.
3. Selection of vertical and horizontal lines. The selection is made using a certain threshold, making near horizontal/vertical lines possible candidates. We store them in a list.



a) b) c) d)

Figure 2. Plate detection. a) detected lines; b) selected horizontal and vertical lines; c) detected rectangles; d) candidate rectangles for string recognition.

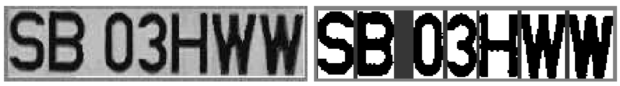
4. Rectangle detection. Using the previously created lists, find two horizontal and two vertical intersecting lines. Create a third list containing detected rectangles.
5. Rectangle selection using a license plate template and edges proportion. Cut out the corresponding image for candidate rectangle and go to recognition stage.

Figure 2 a), b), c) and d) shows the results of steps 2, 3, 4 and 5 for the original image in figure 1 a).

4. String Detection

Following the rectangle detection stage, the string recognition consists of two main steps. First we have to cut from the original image the corresponding area. This is not always the best selection and could contain portions from the plate's edge or from the country's symbols. In all cases, we are computing the rows and columns cumulative histograms for the selected area. Analysis of the shape of the two histograms, we are able to select only the portion of the image containing the letters.

The Maximum Entropy Criterion is also used to threshold the selected image and therefore the characters will be emphasized from the background. The cumulative histogram is again computed for the columns of the binary image. Selection of the characters is straighforward, by inspecting the histogram and finding the gaps between characters. The image area corresponding to each character is then extracted and forwarded to the character recognition stage.



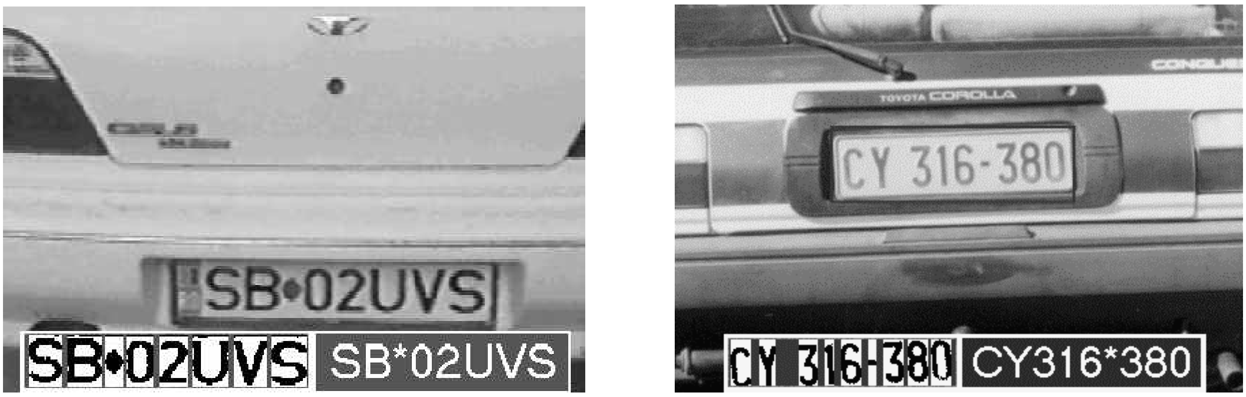
a) b)

Figure 3. a) detected string; b) bounded characters.

Figure 3 shows the results of string detection, after cutting down uninteresting portions of the image through the histogram inspection (a), and the bounded characters in the thresholded image (b).

5. Character Recognition

The character recognition stage is based on template matching and uses the following metric:



a) b)

Figure 4. Test results. Recognized string in a) romanian car image; b) foreign car image.

$$M = \frac{X \circ Y}{\sqrt{(X \circ X)(Y \circ Y)}} \qquad (7)$$

where $X \circ Y$ denotes the inner product of matrices X and Y. If the matrices size is NxM, the product is defined by:

$$X \circ Y = \sum_{i=0}^{N} \sum_{j=0}^{M} X_{i,j} Y_{i,j} \qquad (8)$$

The metric value is 0 for two totally different matrices and 1 for correlated ones. If the matrices are holding binary values of character templates, the metric could be used for matching. Consequently, we have to rescale the character images in order to calculate the metric.

The template-matching algorithm implements the following steps:

1. Select the character image from the detected string
2. Rescale the image to the size of the first template
3. Compute the matching metric
4. Store if highest mach found
5. For all stored templates, goto step 2.
6. Store the index of best mach as recognized character
7. For all bounded character images, goto step 1

If the match metric is below 0.55, then no character has been recognized and a dash "-" is inserted in the string.

The template library was build upon data extracted from vehicle images, comprising letters (A-Z), numbers (0-9) and * (for the romanian technical check sticker). Each character was automatically selected and thresholded using methods previously described.

6. Results

The system was tested on 30 romanian plate images. The total number of characters was 210. Among them, the recognition rate was 88.57% (186 characters). 70% (147) of the character strings displayed in test images where totally recognized. Missed classifications have been caused by dirty plates, obstructing objects (like screws or incorrect positioned technical check stickers) or incorrect positioned camera. License plate where correctly detected on 93% of images. Errors are due to non-uniform illumination, dirty plates or obstructing objects. Figure 4 shows two test images, one containing a romanian plate and a foreign one. Pictures are also showing detected plates and successful recognized strings.

7. Conclusion

We have developed a new method for detecting and recognizing car license plates. We have tested the system on romanian plates and obtained good recognition rates. Results may be improved by refining the recognition stage and testing other classifiers. The system has been tested on a certain number of foreign license plates images, downloaded from the Internet and performed satisfactory. Character templates could be created and added to the system, if different plates are taken into account. Future work is intended to be done in improving and testing the system on a larger number of images. We also intend to integrate the system in a larger traffic management project.

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