AUTOMATIC LICENSE PLATE DETECTION IN COMPLEX CONDITIONS OF ACQUISITION

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Abstract: The work presented here shows a robust method for license plate detection. The term robust in this work is directly related to the efficiency of the system as an automated locator of license plates without human intervention and considering specific characteristics of image acquisition and license plate features. The proposed method is based on the characters and digits thickness found on the Brazilian license plates. Although the method was designed for the Brazilian license plate pattern it can be easily adjusted to other patterns. The results obtained using the proposed method showed a better performance even when compared to commercial systems.

1 INTRODUCTION

Segmentation techniques and license plate recognition from digital images are inserted into the area of computational pattern recognition (Anagnostopoulos et al., 2008) (Souza, 2000) (Campos et al., 2001) (Guingo et al., 2004). Pattern recognition is typically used in commercial applications such as recognition of: speech, face, iris, hands, fingerprints, characters, document classification, and data mining. This paper focus on one special case: location and recognition of license plates from digital images (Guingo et al., 2004).

The main goal of an automatic license plate recognition system is to detect, to segment and to recognize the license plate from a digital image (Anagnostopoulos et al., 2008) (Souza, 2000) (Pedrini and Schwartz, 2008) (de Alencar Lotufo, 2005a). Such a system can be used either in the public or in the private security systems, through specific applications, such as: traffic violations control, access to restricted areas, access to public areas and in criminal investigations (Anagnostopoulos et al., 2008) (Souza, 2000) (Campos et al., 2001) (Gao et al., 2007) (Kwasnick and Wawrzyniak, 2002) (Guingo et al., 2002) (Belvesi et al., 1999).

In the traffic violations control these systems can be used to help recording speed violations, red signal crossing and traffic in restricted areas, in Sao Paulo city, for instance, the traffic in the downtown area is restricted for some vehicles in rush hours, the restriction is based on the last digit of the license plate and the day of the week. Normally these controls are performed using fixed and mobile cameras capturing vehicles images all day long in different illumination, speed and weather conditions, (Souza, 2000) (Campos et al., 2001) (Gao et al., 2007) (Kwasnick and Wawrzyniak, 2002) (Guingo et al., 2002) (Belvesi et al., 1999).

Systems for access control in restricted areas have to verify prior authorization for vehicles to enter or exit a certain area. This type of system is typically used in condominiums, businesses and government offices (Souza, 2000) (Gao et al., 2007) (Kwasnick and Wawrzyniak, 2002).

Systems for access control in public areas are used to check the period a vehicle stay inside, the access frequency and the traffic flow. This type of system is typically used in parking areas where there is no requirement for prior vehicle registration (Souza, 2000) (Campos et al., 2001) (Gao et al., 2007) (Kwasnick and Wawrzyniak, 2002) (Guingo et al., 2002) (Belvesi et al., 1999).

The automatic license plate recognition system has also been used in the public safety area, specifically in criminal investigations. Using images captured by cameras installed at strategic points, the license plate is searched and registered in the transit agencies databases, helping to locate stolen vehicles and to identify possible escape routes (Kwasnick and Wawrzyniak, 2002) (Guingo et al., 2002).

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Usually an automated license plate recognition system has a pre-processing step and three basic steps (Anagnostopoulos et al., 2008) (de Alencar Lotufo, 2005a) (Gao et al., 2007) (Kwasnick and Wawrzyniak, 2002) (Ozbay and Ercelebi, 2005): location and segmentation of the license plate; location and segmentation of the digits / characters in the license plate, recognition of the digits / characters in the license plate.

The pre-processing step is used to enhance the image quality for the following steps. Usually, in this step, it is applied techniques such as histogram equalization and filtering (Anagnostopoulos et al., 2008) (de Alencar Lotufo, 2005a) (Gao et al., 2007) (Kwasnick and Wawrzyniak, 2002) (Gonzalez and Woods, 2005).

The location and segmentation of the license plate usually apply techniques based on morphological characteristics of the plate's background, the characters color, or a combination of both (de Alencar Lotufo, 2005a). The two main techniques used for the plate's background are: edge detection with the Hough transform (Anagnostopoulos et al., 2008) (Gonzalez and Woods, 2005) and artificial neural networks (Guingo et al., 2004) (Kwasnick and Wawrzyniak, 2002). Two of the main techniques based on the characters/digits color are variation and correlation of image objects (Anagnostopoulos et al., 2008) (de Alencar Lotufo, 2005a) (Kwasnick and Wawrzyniak, 2002) (de Alencar Lotufo, 2005b).

The location and segmentation of digits / characters can be performed using horizontal and vertical projections techniques (Anagnostopoulos et al., 2008) (Gao et al., 2007) (Belvesi et al., 1999) (Ozbay and Ercelebi, 2005), searching for an inverted "L" (Souza, 2000) and projections about regular polygons (Guingo et al., 2002).

For the recognition of digits / characters stage the most widely used techniques are: horizontal and vertical patterns projections comparison (Belvesi et al., 1999), neural network using pixel values in the input layer (Anagnostopoulos et al., 2008) (Gao et al., 2007), neural network with the projections obtained from the regular polygons technique (Guingo et al., 2004) (Guingo et al., 2002), and subtraction of digits / characters patterns (Ozbay and Ercelebi, 2005).

The main goal of this work is to develop a robust method to locate license plates in images captured from cameras placed in different roads and under different conditions of: illumination, pose, weather, contrast, and outside noises.

The term robust in this work is directly related to the efficiency of the system as an automated locator of license plates without human intervention and considering specific acquisition characteristics and plate features. Some of the specific plate features considered are: license plate tilt, license plate color, license plate size and position in the vehicle, condition of the license plate, character/digit readability. Some of the external interferences considered are: reflection, illumination conditions, rain, fog, vehicles registration, sensor's noise and license plates standards diversity in the Brazilian legislation (Guingo et al., 2004) (Kwasnick and Wawrzyniak, 2002) (Belvesi et al., 1999).

Some examples of problems addressed in the robustness are presented in Figure 1 which shows a set of images from the dataset used in this work . Note that, only in Brazil, there are eight different patterns for license plates based on the vehicle usage: rental, learning, collection, testing, manufacturers, official, private and diplomatic.

Images with low contrast.

Images with low lighting.

Tilted vehicles.

Vehicles with stickers.

Images with high reflections.

Figure 1: Typical images used in the database presenting a set of problems observed in the image acquisition process.

2 PROPOSED METHOD

One common way to detect license plates in digital images is based on color change frequency (de Alencar Lotufo, 2005a) (Kwasnick and Wawrzyniak, 2002) (de Alencar Lotufo, 2005b), these method, although it can detect license plates positions, it also creates a large number of hypothesis to be tested. The method proposed here is based on color change combined with the thickness of characters and digits found on the license plates reducing the number of hypothesis to be tested. The method searches the images looking for regions showing color variations compatible with the thickness of the digits / characters in a license plate. For each region found in the search process a validation technique is applied. The proposed method was divided into six steps (shown in Figure 2) which will be discussed below.

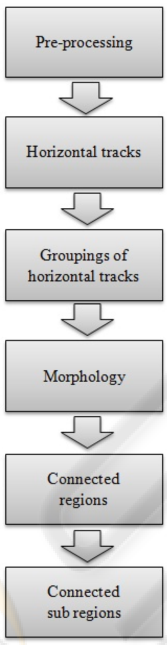

Figure 2: The six steps used in the proposed method.

2.1 Pre-processing

The pre-processing step is used to reduce noise in the acquired images but keeping the edges, mainly in the characters. This step helps to minimize detection of false positives in the following steps (Gao et al., 2007).

In order to define the techniques to be used in the pre-processing steps tests were performed using the mean, Gaussian, median and mean with edge preservation filters. These filters were applied using masks with different sizes (3x3, 5x5 and 7x7). The simple median filter with 3x3 mask size showed the best results, attenuating noise and small inscriptions without damaging the edges of characters. According to Gonzalez (Gonzalez and Woods, 2005) this result was expected.

The next step shows the result of the pre-processing step. The original image used as an example in this section is shown in Figure 3.

Figure 3: Original image.

2.2 Horizontal Tracks

This step aims to locate horizontal tracks compatible with the expected characters sizes. This step considers three parameters: the first parameter defines the color variation limits between the pixels in the same line; the second parameter is the minimum expected width for the characters / digits in a license plate and the third parameter is the maximum expected width for the characters / digits in a license plate.

The parameter that limits the gray level variation is directly related to the image contrast. In the tests performed the value was empirically determined as 20 for the gray level variation.

The parameters limiting the minimum and maximum values for the character/digit thickness in a license plate depends directly on three factors: image width; vehicle width in the image and the standard thickness for the character/digit in the Brazilian license plates.

In this work tests were performed using image resolution with 640 pixels in width. The vehicles are expected to cover from 50% to 100% of this resolution, depending on the number of lanes covered by the radar and each lane are, on average, 2 m wide. The standard thickness of the character/digit is 10 mm wide, as stated in the National Transit Council resolution 231 (CNT, 2007), as shown as the d measure in Figure 4. Considering these features an expected thickness in the acquired image should have something between 3 and 6 pixels, so these are the limiting parameters for minimum and maximum thickness values. The algorithm goes through each horizontal line

Figure 4: Brazilian license plate.

in the image checking the minimum and maximum pixel values for adjacent pixels in order to verify if the difference is within the first parameter. When a valid range is found, the system checks its two neighboring pixels, one at right and one at left, both have to be either higher or lower tones. Notice that the same gradient allows considering license plates with different backgrounds and digit/character color, as far as they preserve the gradient value. Figure 5 presents

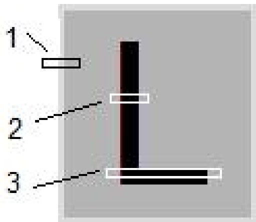

Figure 5: Examples of horizontal tracks located.

three examples of areas that can be found in an image: region number 1 shows a invalid strip, because it has gradients of the same sign at the sides of the middle region. Region number 2 has a central range considered valid by its width and the gradients of opposite signs at the side edges. Region number 3 has a central strip invalid because its width exceeds the limits of the expected thickness of characters / digits.

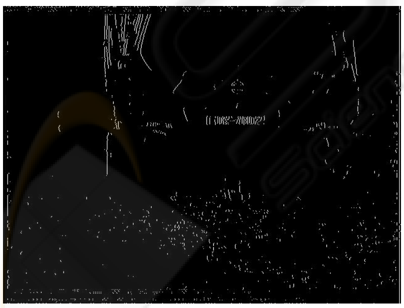

Figure 6: Centers of valid tracks after pre-processing.

When a track meets all the parameters required, the region's center is stored in a new image. Figures 6 and 7 show the results of this step with and without the pre-processing step. Notice that the image in Figure 7 the number of points, possible tracks, which will be further computed and most likely discarded is much larger than the image in Figure 6, due to noise within the image.

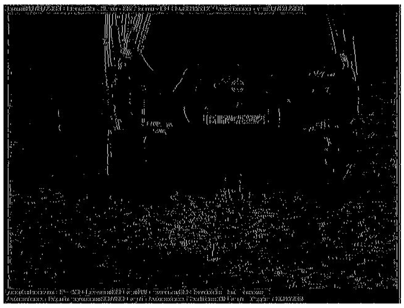

Figure 7: Centers of valid tracks without pre-processing.

2.3 Groupings Horizontal Tracks

The third step is responsible for the location of horizontal track groups, and it uses two parameters. The first parameter sets the maximum horizontal spacing between the centers of horizontal tracks located in the previous step, this parameter is related to the maximum distance between two characters in a license plate. The second parameter defines the minimum amount of horizontal and sequential tracks required to make a license plate hypothesis.

Again, the National Transit Council resolution 231 (CNT, 2007) helps on defining the maximum horizontal space which is computed based on the average distance of 50 mm between characters/digits.

Each character might have from one to three tracks for each character/digit, which gives a minimum of 7 tracks for a license plate in a Brazilian license plate.

At this step the algorithm stores in a new image the tracks found and defines a region which will be tested for a license plate. Figure 8 shows the result of this step, the figure shows three regions with track clusters.

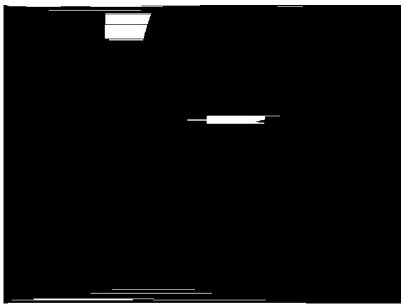

Figure 8: Groups of horizontal bands.

2.4 Morphology

Notice that some regions at the top and at the bottom of Figure 8 are certainly not license plates. These regions are formed by grouping one to three single lines. The fourth step aims to remove these individual tracks through the application of morphological operations of erosion and dilation.

The best results were obtained when it was first applied two erosions, followed by three dilations using a 3x3 square structural element. Figure 9 shows the result of this step, it can be observed only two groups of tracks.

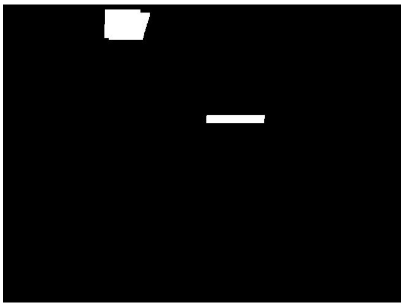

Figure 9: Image after morphological operations.

2.5 Connected Regions

The fifth step finds connected regions based on a four neighborhood (Pedrini and Schwartz, 2008) (Gonzalez and Woods, 2005) (de Alencar Lotufo, 2005b). The regions found are placed in new image and these regions are then called candidates. Figure 10 displays the results of this step it can be observed that only two candidate regions were found.

Figure 10: Image of the candidate regions.

2.6 Connected Sub-regions

This last step performs a validation test for each candidate regions located in the previous step. The process here goes through an exhaustive search using incremental binarizations starting with the value of 10 and going up to the value of 250, thus performing 25 binarizations.

After each binarization the region is searched for six to eight horizontally connected sub regions, corresponding to the number of characters/digits in the Brazilian license plates. The regions that meet these limits are considered valid and, therefore, are considered license plates. Figure 11 shows three images of the region considered a valid region. The top image corresponds to the original image of the targeted region. The middle image shows the binary image obtained in the search process described above, with the location of the seven connected sub-regions presented in the bottom image.

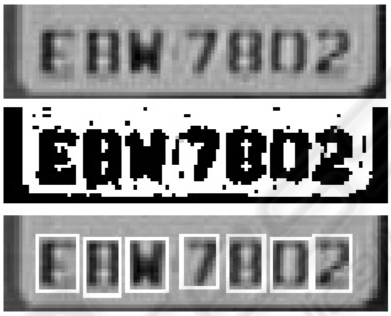

Figure 11: Images of the region considered to be the plate.

3 RESULTS

In order to test the method proposed here a database with 516 images was used. The images in this database were acquired from fixed and mobile radar systems, from four Brazilian highways in the Sao Paulo state. The images have the following features:

- 640 x 480 pixels.
- Format: jpeg.
- Color and Gray level images.
- Frontal or back license plate images.
- Different types of license plates.
- Tilt posed images.
- Light reflections at the license plates, glass or structure.
- Daylight and night conditions.
- Weather variations such as foggy and rainy conditions.
- Cars with or without stickers with different types of inscriptions.
- License plates with different conservation conditions.

The database was also used in two other systems, the SeeCar (HTS, 2009) a commercial system from Hi-Tech Solutions from Israel and the SIAV, an academic system available at Universidade Federal do Rio Grande do Sul (Souza, 2000). Table 1 presents the results obtained by the three systems in the database.

Table 1: Compares the results obtained by the three license plate detection systems in the Brazilian database.

System	Correct license plate detection
Proposed	93,80%
See/Car	75,00%
Siav	54,65%

4 CONCLUSIONS

A new method was proposed to detect license plates based on the Brazilian license plate legislation in images acquired in a diverse range of conditions. The method shows that it is effective on detecting license plates with a detection rate above 90%, a performance above other systems, including a commercial system. The proposed method showed a detection rate about 20% above the commercial system and about 40% above the academic system used in the comparison.

The method also showed that it is robust, changes in the acquisition condition described in the text such as weather conditions, illumination, pose, among others, apparently do not change the detection rate.

The method is completely automatic and can be combined with other methods in order to identify the characters/digits in the license plate.

In a recent survey (Anagnostopoulos et al., 2008) about license plate detection and identification one can check that the average detection rate is around 95%, so the method presented here has a detection rate in the same range. Unfortunately the survey does not mention the type of images used in each algorithm under consideration presented in the survey.

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