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License Plate Identification Based on Image Processing Techniques

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Abstract- A License plate identification system can be used for numerous applications such as unattended parking lots, security control of restricted areas, traffic law enforcement and automatic toll collection. Such a system captures images of vehicles and identifies license plate numbers automatically. Here we present results of a system in identifying the vehicle license plate through digitized photographic images based on image processing techniques. The developed algorithm is based on two basic processing stages; locating the license plate, and, identifying the individual digits and characters in the license plate. The algorithm takes a raster image of the rear view of a vehicle as input and yields the recognized numbers and characters in the number plate as the output. The performance of the developed algorithm has been tested on a set of real images of vehicles. The first part of the system showed that the algorithm performs quite well in accurately locating the license plates (with 97% efficiency). In the second part which is based on neural network techniques, showed high performance in recognizing digits and characters in located plate regions.

Keywords: Neural networks, Character recognition, Segmentation, Image processing

1. INTRODUCTION

Vehicle identification is a research area where image processing methods are used to identify vehicles by detecting and identifying the license plate numbers. Typical vehicle identification systems consist of three main stages. They are the identification and tracking of vehicles through motion, locating the license plate, and accurately identifying the numbers in the license plate.

Although many intensive research studies have been conducted in other countries in the area of automatic vehicle identification, to our knowledge, there is virtually no research studies conducted in Sri Lanka in this area. However, vehicle identification is an essential area in the development of intelligent traffic systems and surveillance. Given the current security situation in the country due to ethnic conflicts, this is one of the areas where there is an urgent need for the development of devices that could be used in variety of situations to ease the security concerns. In addition, the use of vehicles in Sri Lanka has increased rapidly, especially in recent years, due to urbanization and modernization, and thus, traffic congestion in cities has become a major issue. Therefore, control of vehicles and identification of traffic violators to maintain discipline, is becoming a necessary task in many cities. Automatic vehicle identification systems can be used effectively for this purpose [1, 2].

This paper presents results of a developed system in extracting the location of license plates from the still images of rear view of vehicles and the techniques adopted in recognizing the numbers and characters in located plate regions.

From the variety of number plate systems introduced over the years by local authorities, there are several types that are still accepted as valid number plates on local roads. In this project, it was decided to concentrate on the new number plate system, introduced about five years ago by the Department of Motor Traffic in Sri Lanka. Essentially, it consists of plates with white background at the front and yellow background at the rear, and letters in black in both cases. The arrangement of numbers consists of two English letters followed by four digits, separated by a dash (example, GA-1234). In addition, two more smaller letters are placed on plate to identify the Province of issue, namely, CP (Central Province), EP (Eastern Province), NC (North Central), NE (North Eastern), NW (North Western), SG (Sabaragamuwa), SP (Southern Province), WP (Western Province) and UP (Uva Province). As a security feature, a small circular hologram, about the size of a penny coin, is imprinted over the dash between the numbers [3]. In addition, the government seal is imprinted on the license plates above the Provincial identification label.

Many methods have been proposed to detect number plates from vehicle images; ranging from simple statistical methods to neural network algorithms and genetic algorithms. However, in real-time monitoring systems, simple procedures have advantages over complex procedures. Thus, in this work, performance of a simple procedure to extract the plate region of images of rear side of vehicles (yellow number plate) was tested. The basic method for extracting the plate region can be described by the following steps.

1. Input of the original (RGB) image
2. Identification of the yellow regions
3. Edge detection
4. Morphological operation
5. Finding the license plate region
6. Extraction of the plate region (RGB) image for number recognition

After extracting the license plate region identification of individual digits and characters in the plate must be carried out. Before applying the neural network techniques in recognizing the numbers and letters, the following steps were applied in pre-processing the located plate regions.

1. License plate quantization and equalization
2. LP normalizing
3. Character segmentation

At the final stage, neural network techniques were applied in the identification of number plates. Each of the above steps is discussed in detail in the proceeding sections of this paper.

2. METHODOLOGY

The only inputs to the system were the images of vehicles captured by a digital camera. The captured images were taken from approximately 3-5 meters away from the rear of the vehicle so that the number plates were clearly visible in the view. Most of the past research studies in the area of number plate identification have been carried out by converting the RGB original image to other colour spaces such as NTSC, HSV or CIE [4, 5]. In this study, RGB colour space was directly handled by extracting the yellow regions. Since there are pattern recognition problems arising due to poor image quality caused by varying ambient lighting conditions, number plates are often difficult to detect accurately and efficiently in real situations. Based on the pilot tests carried out with several test runs, it was found that the range of yellow colour range in RGB colour space varies between images taken under different light conditions as shown in table 1.

Table 1: Yellow colour range in RGB space

Red	Green	Blue
130-255	80-255	0-85

The captured images were first converted to binary images where the yellow regions were assigned as 1's and others were assigned as 0's.

Fig. 1(a) shows one of the original input images and Fig. 1(b) shows the binarized extracted yellow regions of the original image. It was seen that yellow regions outside the number plate also remained in the binarized image. This is undesirable since ideally we are interested only in identifying the yellow region where the number plate is located. This problem could become much severe if the images are taken in a yellow background or if the vehicle colour itself is yellow. Problem due to the yellow colour vehicle or yellow background was not investigated in this work.

Figure 1: (a) Captured RGB image (b) Binarized extracted yellow regions

After the initial pre-processing to identify the yellow regions, the next step was to find the edges of the identified regions. Edge detection is a process for detecting discontinuities in intensity values. Such discontinuities can be detected by using standard first or second order edge detection operators [6]. In this work, "Canny" edge detection operator was used to detect the edges in the captured images [6]. This operator finds edges by searching for local maxima in the gradient of the image. The gradient is calculated using the derivative of a Gaussian filter. First, the image is smoothed using a Gaussian filter with a specified standard deviation to reduce noise. Then the local gradient and edge detection is computed at each point. An edge point is defined to be a point whose strength is a local maximum. Thereafter the edge points give rise to ridges in the magnitude image. The algorithm then tracks along the top of these ridges and sets all pixels that are not on the ridge top's to zero to produce a thin line as the output - a process known as non-maximal suppression. Finally, the algorithm performs edge linking by incorporating the weak pixels that are 8-connected to the strong pixels [6]. Therefore, this method is more likely to detect true weak edges. Fig. 2(a) shows the binarized extracted yellow regions of the image after processing through the edge detection operator.

$$\begin{matrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{matrix}$$

Figure 2: (a) Edges found by the edge detector operator (b) Diamond-shaped structuring element

After extracting edges morphological operation "dilation" is applied to the images for specifying the plate location. Dilation is an operation that "grows" or "thickens" objects in a binary image. The specific manner and the extent of this thickening is controlled by a shape referred to as a structuring element. Mathematical morphology is a tool for extracting image components that are useful in the representation and description of shape regions such as boundaries [6]. In this work, a diamond shaped structure element (see Fig. 2(b)) was chosen to dilate the binary image. Mathematically, dilation is defined in terms of set operations. The dilation of *A* by *B*, denoted as

$$A \oplus B = \left\{ z \mid \left(\hat{B} \right)_z \cap A \neq \phi \right\}$$

Where Φ is the empty set and *B* is the structuring element [6]. In words, the dilation of *A* by *B* is the set consisting of all structuring element origin locations where the reflected and translated B overlaps at least some portion of *A*.

Generally, this permits identification of yellow regions better than the pure edge detection operation, ignoring for example, the holes (empty regions) inside the plate as shown in Fig. 3(a). The grouping yellow regions in separate filled components and accentuating the separation between them are very useful for the proceeding steps.

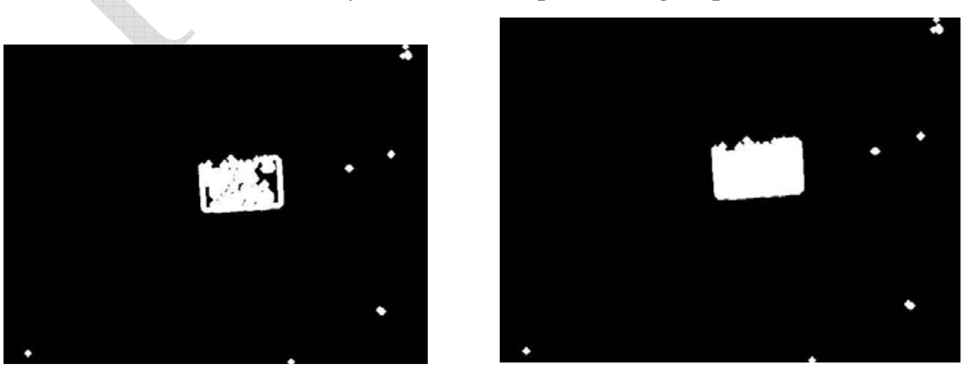

Figure 3: (a) After applying the morphology (b) Flood-filled image

Next, morphological reconstruction was applied to the dilate images by using a flood-fill algorithm. Fig. 3(b) shows an image after applying the flood-fill algorithm. It is very important to consider accurate bounding boxes along the specified areas by selecting the correct dimension. As shown in Fig. 6, some yellow components well outside the license plate area still appear on the image and one must use a cropping process to separate other yellow regions from the license plate region.

In order to do that, bounding boxes for each region was computed. It was found that the smallest rectangle that can contain the region is 1-by-4 vector. By choosing the maximum area which is covered by the bounding boxes, the license plate location was found (see Fig. 4a). To identify the numbers and letters in the number plate though character recognition, the number plate must be free of alignment errors. As shown in Fig. 4a, most of the number plates show rotations with respect to the horizontal plane. By applying the "Radon transformation theory", the angle required to rotate the images to align with the horizontal direction was found. The radon transform represents an image as a collection of projections along various directions. In the final step, the license plate region was extracted and generated as the output (see Fig.4b) which is the main focus of the 1st stage, locating the license plate.

(a)

(b)

Figure 4: (a) Extracted license plate region (b) Localized license plate

As shown in the above figure (Fig. 4b), numbers and characters are not clearly separated from the background. Therefore, additional processing was required to separate numbers and characters from the background. First, located plate regions under various illuminating conditions were turned in to grey colour images and a threshold value was found by investigating the regions where the yellow colour background was present. Using this threshold value, the grey images of the license plates were converted to black and white (binarized image) images with numbers and characters appearing in black colour (see Fig. 5)

Figure 5: Binarized image

All binarized images were then transformed into normalized rectangular shapes (by turning and stretching) of size 100 x 130 pixels and segmented into three separate sections where the lower half contains four digits, upper middle area contains the characters and upper left area contains the provincial identification characters. The images were further enhanced by removing noise from binarized images. Unwanted spots and other signatures did not influence the processing since they were automatically discarded during the segmentation stage due to their unique placements in the standard number plates considered in this work. In order to recognize the true boundaries of the segmented parts, row sum of pixels and column sum of pixels were considered.

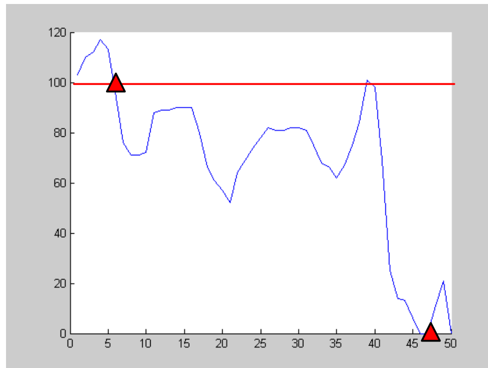

Figure 6: Normalized number area – row sum

Upper and lower boundaries was identified by searching for a signal whose row sum is greater than or equal to a threshold value within the first 15 rows and minimum row sum beyond the 40th row. Threshold value was chosen by analyzing the available images. For example, Fig. 6, shows the bandwidth of the signal which is between pixel rows ~6 and ~46, which defines the upper and lower boundaries. Similarly, by considering the column sum, left and right boundaries were identified. Finally, the noise free images were resized to the normalized dimension as shown in Fig. 7.

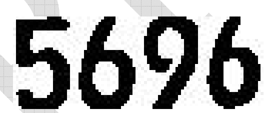

Figure 7: Extracted plate area with numbers

The segmented images were then further processed to identify the vertical boundaries of the individual numbers. Fig. 8a shows the column sum of the cropped image. The vertical boundaries can be clearly identified in the figure. By taking the height to be 25 pixels per digit, each image was resized and further segmented into 25x15 pixels (see Fig. 8b). The same process was carried out to segment the characters in the other two sections of the licence plate.

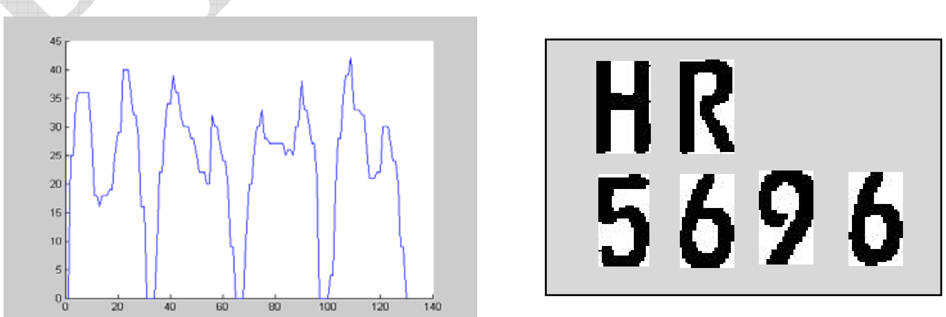

Figure 8: (a) Normalized number area – column sum (b) Segmented numbers and characters 25x15

Finally, each segmented digit was compared to standard digits saved in a dataset, using neural network techniques. After interpolations, approximations and decisions, the algorithm yields the closest digit in the dataset to the segmented digit.

4. PERFORMANCE

Pilot tests were carried out to test the performance of the developed system based on the accuracy of identification of sub-components by the image processing algorithms and to study the processing time of the system against the image resolution. The system was designed and developed in Matlab using the image processing toolbox. The test images were taken under various illumination conditions. The input images were colour images with a maximum resolution of 1600×1200 pixels. The results of the test are given in Tables 2 and 3.

Table 2: Test results of license plate detection module

Sub-component	Accuracy	Percentage
Extraction of yellow regions	30/30	100%
Extraction of plate region	29/30	97%
Character Recognition	29/30	97%

The developed algorithm shows 100% accuracy in extraction of yellow regions and 97% accuracy in extraction of plate regions and character recognition. Table 3, shows the time taken to execute the complete code in an Intel Celeron A6R notebook computer running at 1.6 GHz clock speed. According to the results, the algorithm takes 3±1 seconds to identify and produce the plate region as the output for images taken with 640×480 resolution. About 70% of the execution time has been consumed in the extraction of the yellow regions.

Table 3: Test results of execution time

Image quality	Average execution time
1600 x 1200	50±1 seconds
640 x 480	3±1 seconds

4. CONCLUSIONS

In this paper, we presented an image processing technique, designed for the extraction of plate regions of newly introduced yellow colour rear vehicle license plates with black letters from photographs of vehicles. First the yellow regions were extracted, and then through a mathematical morphological operation, the plate region was extracted. Based on the experimental results, criteria to identify the yellow regions in RGB colour system was presented.

As expected, the execution time of the system was highly depended on the resolution of the captured images converted to gray levels. The method discussed here fails in locating a license plate if the colour of the vehicle itself or the background is yellow. However, pilot tests showed that the algorithm was highly successful in finding a plate under various illumination conditions. Most of the yellow regions could also be eliminated by investigating the relationship between the length and the width of areas.

The second stage of the system which is the character recognition stage can be easily improved. Preliminary work with the neural network techniques showed highly promising results in recognizing individual digits and characters. Future work could focus on identifying the plate under any vehicle colour or the background irrespective of the environment.

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