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Mathematical Morphology Methodology for Extraction of Vehicle Number Plates

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***Abstract*—** This paper presents a methodology for extraction of the vehicle number plates from the vehicle images using hybrid mathematical morphology techniques. The main idea is to use different morphological operations in such a way so that the number plate of the vehicle can be identified precisely. The methodology makes the task of extraction of the number plate independent of color, size and location of number plate. The proposed approach involves five different processes, these are, image enhancement, morphing transformation, morphological gradient, combination of resultant images and extracting the number plate from the objects that are left in the image. This algorithm can quickly and correctly detect the number plate area from the vehicle image. Some vehicle number plate norms are also presented in this paper.

***Keywords*—** Mathematical morphology, morphological gradient, vehicle number plate, morphing transformations, image enhancement.

I. Introduction

IN the current information technology era, the use of automations and intelligent systems is becoming more and more widespread. The Intelligent Transport System (ITS) technology has gotten so much attention that many systems are being developed and applied all over the world. Vehicle number plate recognition (VNPR) has turned out to be an important research issue. VNPR has many applications in traffic monitoring system, including controlling the traffic volume, ticketing vehicle without the human control, vehicle tracking, policing, security, and so on.

The most vital and the most difficult part of any VNPR system [11] is the detection and extraction of the vehicle Number plate, which directly affects the systems overall accuracy. The presence of noise, blurring in the image, uneven illumination, dim light and foggy conditions make the task even more difficult. In this paper we propose a detailed and novel method for accurately detecting the location of vehicle number plates. The proposed system can work very accurately in almost any environment, time of day, and conditions.

There are some international, national or local standards for vehicles. One sample is presented in the Appendix to this text. In China, the basic norms [12] for the number plate are presented. Some regional co-operations such as European Union (EU), have plates [13] that define the country, the place of registration, etc. In this text, Chinese, Pakistani, and Kuwaiti plates are represented.

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II. Related Work

The problem of automatic VNP recognition is being studied since the 90's [5], [8], [10]. The early approaches were based on characteristics of boundary lines. The input image being first processed to enrich and enhance boundary line-information by using such algorithms as the gradient filter, and resulting in an image formed of edges. The image thus processed was converted to its binary counterpart and then processed by certain algorithms, such as Hough transform, to detect lines. Eventually, couples of 2-parallel lines were considered as a plate-designate [6], [11].

Another approach was based on the morphology of objects in an image [1], [7]. This approach focuses on some salient properties of vehicle plate images such as their brightness, contrast, symmetry, angles, etc. Due to these features, this method could be used to detect the similar properties in a certain image and locate the position of number plate regions.

The third approach was based on statistical properties of text [3], [4]. In this approach, text regions were discovered using statistical properties of text like the variance of gray level, number of edges, edge densities in the region, etc. This approach was commonly used in finding text in images, and could well be used for discovering and designating candidate number plate areas as they include alphabets and numerals.

In addition, there have been a number of other methods relating to this problem focusing on detecting VNP using artificial intelligence and genetic algorithms [2], [9]. These systems used edge detection and edge statistics and then AI techniques to detect the location of the number plate-designate area. All of the systems discussed above have some kind of limitations for example they are plate size dependent, color dependent, work only in certain conditions or environment like indoor images etc. The method that we are proposing is independent of color, size, location and angle of the number plate of the vehicle.

The organization of rest of the paper is as follows: Section III describes the proposed technique adopted for extracting the number plates of vehicles, while in section IV we describe the experiments performed on the images. Section V concludes our work.

III. PROPOSED TECHNIQUE

The proposed technique for the extraction of vehicle number plates consists of the following five processes, as shown in Fig. 1. Image enhancement, morphological transformation, morphological gradient, combination of the two images obtained from the top or bottom hat transformations and morphological operations, resulting in the vehicle number plate designate confirmation. The two steps morphological transformation and morphological gradient may be performed in parallel using the parallel processing software or hardware.

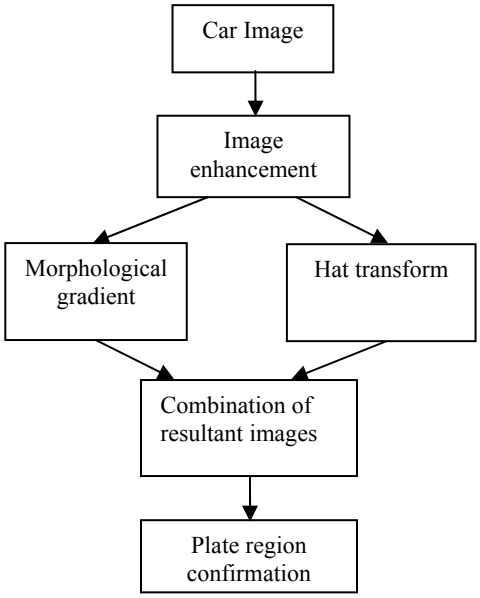

Fig 1: The proposed system

We now discuss the above mentioned steps in detail:

A. Image Enhancement

Image enhancement is used for pre-processing in the image before any morphological operations are performed. In this process, we use methods that include adjusting the intensity of the image and reducing the contrast in the image. The technique used for intensity adjustment is known as histogram equalization. The contrast in the image can be reduced by several methods that are normally used for contrast enhancement. Secondly many images contain noise and are blurred that may be due to image capturing equipment. The noise removal algorithms and the de-blurring algorithms were also used in this process where required.

In addition, techniques are used for color enhancement in case of images that need color correction.

B. Hat Transformations

Hat transformations can be used for contrast enhancement. There are two hat operations and are known as the top hat and bottom hat transformations [7]. Tophat operation is actually the result of subtraction of an opened image from the original one, mathematically,

$$th = f - (f \circ b) \qquad (1)$$

where, f is the input image and b is the structuring element.

2a

2b

Fig 2a: Original image and 2b shows the result of intensity and contrast adjustments.

Whereas in the case of bottomhat operation, it is defined as the closing of the image minus the image, mathematically,

$$bh = (f \bullet b) - f \qquad (2)$$

The Bottomhat transformation may be used where the image is the complement. The tophat operation suppresses the dark background and highlights the foreground objects.

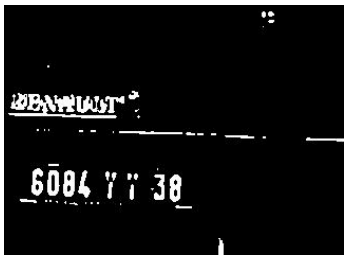

Fig 3: Resultant binary image after hat transformation and removing small features from the resultant hat image.

We see that no matter of what color the number plate is, the characters (i.e., text and numerals) on the vehicle plate are usually bright colored and contrast the color of the plate. So this operation highlights the characters and suppresses the irrelevant background. If we obtain the binary of the resulting image and remove very small scale features or components, we see that only a few plate designate foreground areas are been left and most of the irrelevant objects have been removed.

C. Morphological Operations

Mathematical morphology commonly refers to a broad set of image processing operations that process images based on shapes. There are several morphological operations but we use only dilation and erosion for the purpose of number plate extraction. The subtraction of an eroded image from its dilated version produces a morphological gradient, which is a

measure of local gray level variation in the image. Mathematically,

$$g = (f \oplus b) - (f \theta b) \quad (3)$$

We have used the morphological gradient for the detection of plate designated area. First the image was eroded by a disk shaped structuring element. Then the original image was again eroded using the same structuring element. After that the eroded image was subtracted from the dilated version. This produces an image with very less designated areas for the probable vehicle plate. After this step change the resulting image into binary and remove the smaller components which are categorized as noise.

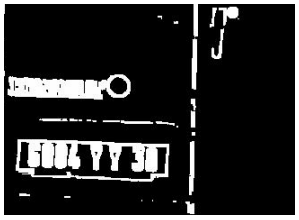

Fig 4: Binary image after morphological gradient and noise removal.

D. Combination of Resultant Images from Hat Transform and Morphological Operations

There were some extra designated objects or regions that were present in the result of hat transformation and there were different designated areas produced in the morphological gradient, other than the probable number plate object. So to combine the results of both and remove the extra objects we intersected the both images. This gave us even fewer designated areas which were present in both of the resulting images. i.e. the hat transformation and the morphological gradient.

Fig 5: Result of combining the resultant images.

E. Plate Region Confirmation

We observed that there were many horizontal and vertical lines which are present in the resultant combined image and which could possibly bring some error in the final results. So to remove those horizontal lines we opened the image with a horizontal line shaped structuring element and subtracted that image from the intersected image. This considerably removed some false designate areas such as the bumper lines or the horizontal lines of the front or rear lights. After that we dilated the image with a rectangular structuring element so as to combine the objects on the number plate into one object.

Next, we applied some checks and conditions which are based on the properties of the vehicle plate, for example the area of the plate, aspect ratio and the density of the region of the number plate were checked for all the remaining objects in the image. The result by using these features was that components other than the probable number plate designate are deleted, and we are left only with the number plate area. Lastly we calculate the bounding box around that object and get the coordinates of that bounding box, which are the actual coordinates of the vehicle number plate.

6a

6b

Fig 6a: Result of applying conditions like area, bounding box and aspect ratio. 6b shows the final plate area detected in the image within a green rectangle.

IV. EXPERIMENTS

Experiments were performed to test the efficiency and accuracy of the proposed technique. 100 color images were used for testing the technique. All the images being normalized to just about 640 x 480 because some images were double this size and also it is normal to use the size. For improving the complexity and generality of the test databases, the images were acquired from the highways, car parks, at different lighting condition (cloudy, sunny, daytime, night time) and different kinds of vehicle (van, truck, car).

7a

The images were taken of different color and variable sized number plates, also the images were irrespective of the angle and orientation of the camera. Some images contain Chinese and Arabic characters as in Fig. 7. Also many images were acquired using the worldwide web. These results report a high accuracy rate of above 96%.

7b

7c

Fig 7: The vehicle number plates in the images as well as an extracted vehicle plate.

V. Analysis

Comparison of the results derived from proposed method with other techniques. The other methods were 1. Feed-Forward Neural Network [9], 2. Hough Transform [6], 3. Back-Propagation Network [8], and 4. Maximum Entropy method [11], respectively. Comparison of results has been tabulated in Table I, with these methods and our proposed method, where the new method corresponds well to the other methods of extraction. In our case, there were some cars that had no number plates attached to them.

Table I Comparison of results

Method	Correct	Reject	Other	No plate
1	90.00 %	8.00 %	2.0 %	
2	92.85 %	7.15 %		
3	95.0 %	5.00 %		
4	93.00 %	7.00 %		
PM	95.00 %	2.00 %		3.00 %

VI. Conclusions

This paper describes an algorithm that allows the extraction of vehicles' number plates using a hybrid of mathematical morphological techniques. The main advantage of the technique that we propose is the high accuracy of the technique that works irrespective of the color, size, location, and angle of the number plates. Therefore, this technique can be used effectively in any environment in any country.

Although the technique is quite efficient enough to work very well in the real time environment but currently the technique proposed lays more emphasis on the accuracy of the overall system, while the some more work is to be done to make the technique more efficient. The authors hope to develop a vehicle detection system in which the VNP is a part, we want to use vehicle noise signature for detection of vehicle through its engine sound. Also, future work is intended to improve the overall efficiency of the system so as to make it computationally more effective.

Appendix

Figure 8 shows the sample plate with its measurements. This is a sample of number plate that is used on Chinese vehicles. In this plate [12], first there is a Chinese character that represents one of the provinces, municipalities, autonomous regions of China. The second is the Roman letter to represent the city. The third and fourth can be a letter or a number, while all the remaining are numbers.

Also, this figure shows that the numbers are embossed on a metallic sheet. The background color is blue, the characters or numerals are white. For buses and other vehicles, the typical background colors can be white, yellow, and black. In buses, motorcycles, the front and rear number plates are different in dimensions.

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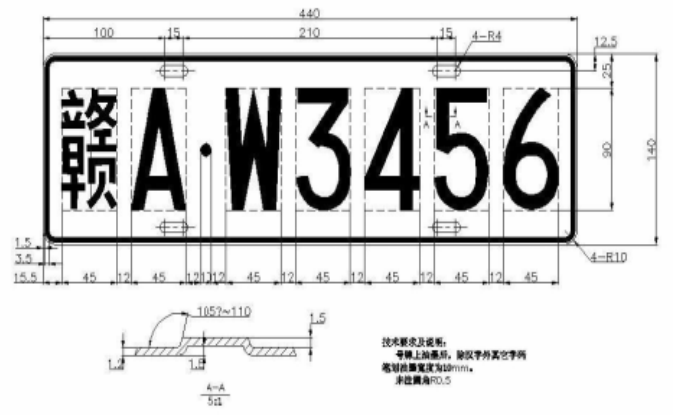

Fig 8: Sample number plate