A Study of Automatic License Plate Recognition Algorithms and Techniques

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ABSTRACT

One of the most useful techniques in traffic management, speed control and security improvement in big cities is Automatic License Plate Recognition (ALPR). During the last two decades many techniques for license plate detection have been developed. Four methods suggested for vehicle license plate recognition are studied and compared in this paper. The main focus of all of these methods is on suggesting a robust, and at the same time simple solution to resolve the common issues in license plate recognition. The main issues taken in to consideration include sensitivity of these systems against environmental and geometric changes. The first method is based on creating a cascade classifier using statistical features. The second method uses a combination of Hough transform and Contour algorithm in a boundary line approach. The third method makes benefit of mean shift approach in the spatial-range in order to create candidate regions, and Mahalanobis classification for character identification, and the fourth system uses morphological operations to decrease the number of candidate regions.

Keywords

LPR, Mean Shift, Mahalanobis classification, Gradiant Density Variants

1. INTRODUCTION

License plate recognition (LPR) plays a significant role in many applications relevant to transportation systems such as traffic management and analysis, speed control, automobile theft prevention, parking lot management, and many other research areas. The effect of variable illumination, complicated backgrounds, and the distortive effect of vehicle speed on license plates are some of the main problems which any proposed LPR system has to overcome. However, many advances have been made in the field to diminish such restrictions. Mainly, efforts have been put on suggesting feasible approaches that are insensitive to environmental changes; for instance, the change in illumination as well as geometric changes, such as picture rotation because of the change in view point. In turn, the mentioned problems can increase the complexity of the proposed solutions; hence, a compromise is always needed to be taken in to consideration between system's robustness and its complexity. Time consumption is another issue in some of the proposed LPR systems. Specifically, it is an important problem among iterative methods. Primarily, an LPR system has two objectives: first, it should find out the license plate location, and second, it should recognize the alphanumeric characters on the plate. License plate locations are usually found based on their characteristics. These characteristics can include the color, size, grayness [9], and rectangularity. Character identification is planned based on lines, alphanumeric character aspect ratio, the gaps between the characters, and the organization of the characters. Furthermore, character separation plays a crucial role in character identification. Some of the proposed methods for character separation include morphology [9] and projection [4]; both of which have their own advantages and disadvantages. For example, the morphology needs the size of a character as an input, and in the projection method, it is assumed that the direction of the license plate is determined. . This paper is organized as follows: An LPR method, which uses both global statistical features and local Haar-like features [4] is studied in section 2. An automatic license plate recognition system is studied in section 3. In section 4, an LPR system that is based on the region of the candidate areas is explored. In section 5, a LPR system that uses morphological operations is studied. A comparison and discussion is given in section 6, and a conclusion of the paper is given in section 7.

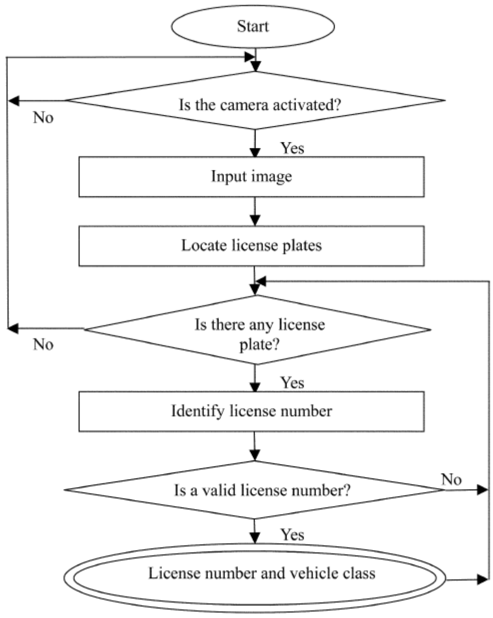

Figure 1: A Flowchart of automatic license plate recognition

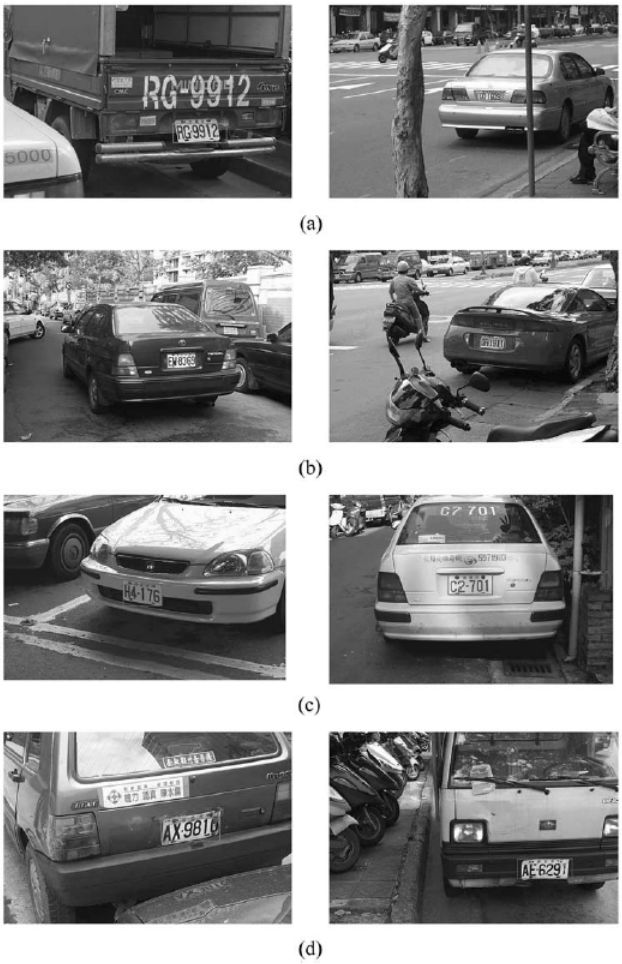

Figure 2: Example of issues in LPR: (a) Complex scenes (b) Different environment (c) Various Illuminations (d) Damaged plates

2. AN LPR METHOD WITH GLOBAL STATISTICAL FEATURES AND LOCAL HAAR-LIKE FEATURES [6]

In this method, a cascade classifier is constructed to recognize the license plate region by removing the background part of the image. The goal of creating a cascade classifier is to increase the speed of recognition.

First, the classifiers are created by the use of global statistical features. Other classifiers are then constructed by using the AdaBoost learning algoritm. The new classifiers are made based on arbitrary Haar-like features. Finally, the cascade classifier, which is a combination of the above-mentioned classifiers, is made by using the global and local features.

In this method, two sets of data samples are prepared first: the positive data samples, which includes the regions containing the license plate and the negative data samples, which do not contain the license plate. The Gradiant Density, which is a global feature, is calculated for all of the samples. The reason for using the samples' Gradiant Density is that it is hard to construct an edge detector in practice; in turn, the edge detector works because the regions containing the license plate have the tendency to have dense edge data. Thus, using the samples' Gradiant Density makes the algorithm simple. The next step is constructing a classifier based on an arbitrary threshold. The classifier then sorts all the positive samples as positive. During this process, some of the negative samples are also sorted as positive by the classifier. These negative samples are called "false positives." The positive samples (including the false positive ones) are used to construct the second layer classifier. The second layer classifier operates based on another statistical characteristic called Density Variance. The reason for using Density Variance is that by modifying it, the license plate can be separated from the background; therefore, the block of the picture that contains the license plate is usually distributed evenly. The input samples are classified by the classifier of the second layer. Similar to the first stage, the samples classified as positive are used to build the third layer of the

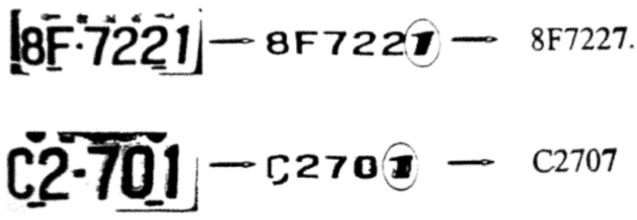

Figure 3: Examples of Failed plates number identification

Figure 4: Example of successfull license number identification (a) Locating license plate (b) Region Segmentation (c) Licence number identification.

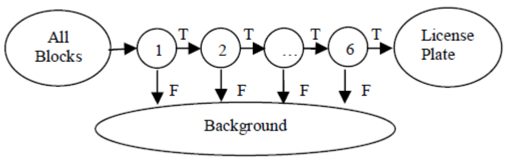

Figure 5: A flowchart of the cascade classifier development process

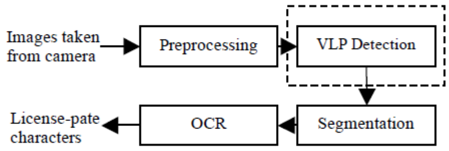

Figure 6: The work flow of the cascade classifier 1,2,...,6 represent layers

classifier. Likewise, the samples sorted as positive by the third layer classifier are used to construct the forth layer and so on.

3. AN AUTOMATIC LICENSE PLATE RECOGNITION SYSTEM [10]

The use of Hough transform slows down the detection speed due to the number of calculations needed when dealing with pictures with a high resolution. The main advantage of this method is the use of a combination of Hough transform and Contour algorithm, which optimizes the recognition speed in processing images which are taken from various positions.

3.1 License plate detection

This method includes three steps: license plate position detection, character segmentation, and character recognition. In this method, the vehicle license plate detection stage is based on a boundary line approach, which uses a combination of Hough transform and Contour algorithm. Projection method is used in the character separation step. For the number recognition step, an OCR module, implemented by Hidden Markov model, is used. In the License plate detection stage, the picture is first sent to a module so that its boundary characteristics will be reinforced. The tools that this module uses are graying, normalization, and histogram equalization. After the boundary reinforcement step, the Hough transform is implemented to extract the lines from the image. However, in order to increase the speed and accuracy of detection, a combination of Hough transform and Contour algorithm is used. First, Contour algorithm is used to derive the boundary of the pre-processed image. Then, the lines resulted from Contour algorithm are transformed to Hough peculiarities in order to discover two parallel lines, which can be considered as candidate regions.

3.2 Candidate Verification

After calculating how the obtained lines are tilted from a straight horizontal line, a transformation is made to make them straight. In the next step, the ratio between the height and width of the candidate is measured. The height to width ratio is then compared with the predefined template in order to find out if the candidate region has the possibility of containing the license plate. Besides the height to width measurement, another solution would be to use the horizontal cuts and observe the number of the objects being cut by them. If the number of objects being cut is in the range of the number of alphanumeric characters in the sample plate, the candidate region can be considered for the next step. The following stage is segmentation. In this stage, a horizontal projection is used to segment the rows in two row plates. The regions with the lowest projection value are the terminal of the row. After this segmentation, we can find out if a candidate is a license plate or not by looking at the number of the characters in the candidate regions.

In the character recognition stage, the goal is to sort a character in to a possible alphanumeric character (numbers and Latin letters). Samples that are extracted from real license plate pictures with some amount of noise are used in comparison with the plates that have a similar sound. In order to have better recognition, the features of different regional license plates are used in the model.

4. AN LPR SYSTEM BASED ON THE REGION OF THE CANDIDATE AREAS [11]

By using a mean shift in the spatial-range domain of color images, this method proposes a system which shows a good robustness to interference characters and a reliable accuracy in LPR.

4.1 Candidate region detection

This method is used to locate the license plates from a picture taken by a camera. In this procedure, mean shift method [4] is applied in order to produce candidate regions. Mean shift is a way to look for the place where the density function takes its local maxima. Moreover, a practical method based on mean shift is applied for in the spatial-range domain of color images [1] for picture segmentation. When mean shift is applied to a picture pixel, the output is the value of the convergence point. For image segmentation, the points with convergence points close to each other are mixed in order to have uniform regions in the picture. In the segmentation stage, the input picture is first normalized by a uniform filter. Then, the segmentation is done by using the means shift procedure in spatial-range domain to the normalized picture where the segmentation parameters are arbitrary [4]. After this step, we can see that the pixels from the common region have the same color. The yielded regions are the candidate regions.

4.2 Feature extraction

In the next step, we need to find out if the candidate regions contain the license plate or not. This process is done by researching the features of the region, such as rectangularity, aspect ratio, and edge density.

Rectangularity is the amount of closeness of an object to its minimum associated rectangle (MER) [8]. Here, rectangularity is the ratio of the number of pixels in a region to its MER. For finding out a region's MER, we can consider it as a solid object and rotate it in steps of an angular unit. The rotating angle in which the enclosing rectangle takes its minimum value should be selected, and the size of the enclosing rectangle can be used for the rectangularity test. Moreover, the enclosing rectangle's dimension can be used for the aspect ratio test, which is the ratio of the width to the height of an object's MER. The pixel values in the regions where the characters exist have higher local variances. Edge density is used to quantize the local variance of the pixel values. After extracting the characteristics of the candidate regions, three solutions are used to distinguish the region containing the license plate and the background regions: 1) assigning thresholds for the features and make a decision regarding the region based on them 2) making a future map by using a number of selected key features and then binarizing the map in to a binary image. After this step, morphological operations are used to recreate the final regions from the segmented blocks 3) Using a classifier. A combination of all these features is used to produce a feature vector, and then a classifier that works based on the minimum distance is used to make a decision about the candidates. In this classifier, a Mahalanobis distance [2] is used as the distance measurement. In this testing method, the Mahalanobis distance from the produced feature vector to the mean vector of the two regions (one with a plate and one without a plate) is measured. In the below equation, when d<d3 or d2<d3, the region is decided to be the license plate region.

$$d_k^2 = \|\mathbf{x}-\mathbf{m}_k\|^2 = (\mathbf{x}-\mathbf{m}_k)'\mathbf{C}_k^{-1}(\mathbf{x}-\mathbf{m}_k), \quad k = 1, 2, 3.$$

Figure 7: Mahalanobis Classification

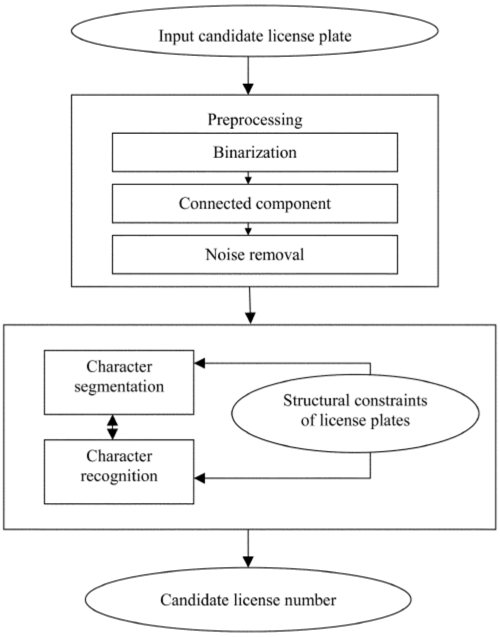

Figure 8: A Flowchart of Region-based licence plate recognition

5. LOCATING LICENSE PLATES BY USING MORPHOLOGICAL OPERATIONS[7]

This method tried to use the contrast feature for extracting candidate regions. The reason for using this feature is its insensitivity to many geometrical changes such as the color of the cars, camera translation, and rotations, and the reason for using a method based on morphological operations is that it lessens the number of candidate regions, and thus, makes the method work faster. This system consists of three steps. Extracting the contrast feature of the images by using morphological operations is the first step. The next step is to use reconstruction algorithm to recover the segmented license plate region. Lastly, the license plate is verified regarding to the number of its characters, and by using a proper character identification method. A flowchart of the system is given in the figure 9.

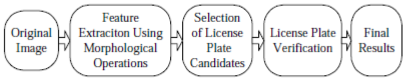

Figure 9: Flowchart of the system

5.1 Feature extraction

Morphological operations are used in this step to find the candidate regions based on the fact that the plate regions have higher contrast than the background regions. At first, a smoothing operation is applied to remove the noises from the image [4]. This step follows with closing and opening operations to obtain IC and IO [4], respectively. A differencing operation is executed to IC and IO in the next step to recognize the vertical edges. In order to make the recognition criteria easier, this system joins the adjacent vertical edges together to create a unified segment. This process is done by a closing operation. At the last step of the feature extraction part, a labeling process is used to find the sections similar to a license plate.

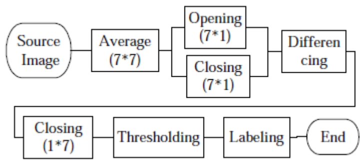

Figure 10: the feature extraction flowchart

5.2 Segmentation

The license-plate-similar regions extracted by the labeling process may include the unwanted objects such as trees, street signs, and window frames, which are sorted in the candidate regions.

5.3 Extracting the candidate regions

One method is to measure the density of the region. If w is the width, and h is the height, and A is the area of the region, then the density of the region is: den = A/(hŒw). Another criterion is to measure the width to height ration of the region and compare it with a sample license plate. The third method is to see if the size of the region is big enough to be considered as a license plate area, i.e. to see if the characters of a typical license plate can be fit in the region.

5.4 Recovering the fragments of the license plate region

Elements such as noise or environmental changes play an intruding role in license plate verification. These factors can make the extracted region of the image incomplete, i.e. the region is only a part of the license plate. The recovery stage is applied to reconstruct the license plate image before the final recognition step is taken. A typical algorithm used for the recovery process is vertical intensity projection, by which the average width and height of alphanumeric characters in the segment are measured, and according to this information, the whole plate is recovered. But this method is variant to the changes in scaling and rotation of the plate. A better approach is to use the cluster-based algorithm proposed by Jun-Wei Hsieh et al.[4] to measure the useful geometrical features of the characters and then recovering the license plate.

Figure 11: The region (a) is a part of (b), and needs to be recovered.

5.5 Modification of inclined plates

In some of the cases the plates are inclined in the images, because of the angles between the car license plate and the camera, or the camera orientation. A procedure needs to be used to modify this inclination. If the coordinate of the center of the plate is (xc , Yc), Wr as its widh, and Dr represents the difference between the heights of the first character and the last character in the inclined license plate Rp, and Rmodified denotes the modified plate, then for each pixel (x, y) of RP, the intensity can be modified as follows:

$$RModified\ (x\ y) = Rp\ (x, y - (x - xc)Dr/Wr)$$

color.png

Figure 12: Examples of the cases at which the car and the plate have similar colors

Figure 13: Examples of the cases at which the plates are inclined.

6. COMPARISON OF THE SUGGESTED SYSTEMS AND THEIR PROBLEMS: [5]

6.1 An LPR method with global Statistical features and local Haar-like features

This method uses AdaBoost algorithm, which selects a number of algorithms from a large group of weak classifiers, in order to construct a strong classifier. This algorithm needs a large number of license plate images which are manually obtained from a number of images including the backgrounds. The images are obtained in different illumination conditions. The problem with method is that since the system needs a big set of training pictures, it requires a larger memory to run, which is not suitable for embedded systems. Another problem with the systems using AdaBoost is that they are slower than the edge-based methods, and thus, they are not suitable for real time embedded systems. Moreover, this system is very sensitive to the distance between the camera and the license plate as well as the view angle.

6.2 An Automatic License plate recognition system

This method, which uses combination of Hough transform and contour algorithm, is one of the best tools used to detect the lines from a binary image. The biggest disadvantage of Hough transform is its execution time due to the fact that it needs too much calculation when applied to a binary image with higher resolution. Consequently, in this system, a combination of Hough transform and contour algorithm is used. Moreover, the pre-processing stage at the first step of this method can partially improve the timing problem. However, this system can falsely detect the background objects, such as the headlight, or windscreen as the license plate, because of the parallel lines that they contain. Hence, a number of steps need to be taken to obtain the license plate form the image.

6.3 An LPR system based on the region of the candidate areas

This method uses a mean-shift procedure in a spatial-range domain to segment a vehicle image to obtain license plate candidate regions. A main problem with this method is when the car and its license plate have the same color. The use of mean -shift method also makes the system inefficient when dealing with blurred pictures, or the ones which are complex in color.

6.4 Locating license plates by using morphological operations

Morphology is an image processing method which relies on the analysis of the images based on their shapes. This system can detect many objects which have a relatively similar shape to a license plate as a candidate region. To distinguish between the license plate and the background, features such as aspect ratio, density of the regions, and width to height ratio are assessed. One problem with this method is that its accuracy is decreased when dealing with more complex images due to its sensitivity to additional edges, and lines which are too independent to be joined with other lines. This issue makes this system have the lowest accuracy among the studied methods. Furthermore, compared to the other algorithms it needs more computations, which slows down its speed significantly. However, its implementation is simple.

7. CONCLUSION

Vehicle license plate recognition systems play a very important role in many traffic management and security systems such as speed control, automobile theft prevention, and parking lot management. Many research efforts have been conducted to suggest a robust method. A study of four suggested methods for vehicle license plate recognition was given in this paper as well as a comparison of the methods and a review of their flaws. The first method uses global statistical features such as Gradiant Density, and Density Variance, as well as Haar-like features in order to have a fast and accurate detection. The sample classified as positive are used to construct the next layer of classifier. The second method is planned based on a boundary line approach. This method uses a combination of Hough transform and Contour algorithm in order to have a faster detection method. In this method, two approaches are used for further recognition of the candidate regions: width to height ratio measurement, and applying a horizontal cut to the regions. For more improvement in choosing the regions containing the license plate, horizontal projection method is used for segmentation. In the third approach, mean shift approach in the spatial-range domain is applied to each pixel in order to find the value of the convergence point for each pixel. The convergence point value for each pixel is used to find the candidate regions. Rectangularity test, aspect ratio test, and edge density tests are the solutions used in this method, in order to better distinguish the regions containing the license plate, and the background. Finally, the Mahalanobis classification is used to find the license plate region. The forth method uses morphological operations in order to lessen the number of the candidate regions. This system consists of three steps: 1) Extracting the contrast feature of the images by using morphological operations,2) using a reconstruction algorithm to recover the segmented license plate regions, and 3) license plate verification regarding to the number of its characters, and by using a proper character identification method.

Finally, a comparison of the four methods is given. The first system needs a large memory which is not appropriate for embedded systems, and is slow, which is not appropriate for real time systems. The second system can falsely detect some of the background objects due to their parallel lines. The third system has the problem of dealing with the cars that have the same color as the license plates, as well as with images with complex colors. Finally, the fourth system has the problem of its low accuracy compared to the other methods as well as its low speed due to the intense calculations it needs.

[3]

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