A Real Time Vehicle’s License Plate Recognition System

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Abstract—Automatic License Plate Recognition system is a real time embedded system which automatically recognizes the license plate of vehicles. Most of the ALPR systems are built using proprietary tools like Matlab. The aim of this paper is the extraction of vehicle license plate information from an image or a sequence of images. The extracted information can be used with or without a database in many applications, such as electronic payment systems (toll payment, parking fee payment), and freeway and arterial monitoring systems for traffic surveillance. ALPR as a real life application has to quickly and successfully process license plates under different environmental conditions, such as indoors, outdoors, day or night time. It should also be generalized to process license plates from different nations, provinces, or states. These plates usually contain different colors, are written in different languages, and use different fonts; some plates may have a single color background and others have background images. The license plates can be partially occluded by dirt, lighting, and towing accessories on the car.

Index Terms—Automatic license plate recognition (ALPR), automatic number plate recognition (ANPR), car plate recognition (CPR), optical character recognition (OCR) for cars.

I. Introduction

Automatic license plate recognition (ALPR) plays an important role in numerous real-life applications, such as automatic toll collection, traffic law enforcement, parking lot access control, and road traffic monitoring [1]-[4]. ALPR recognizes a vehicle’s license plate number from an image or images taken by either a color, black and white, or infrared camera. It is fulfilled by the combination of a lot of techniques, such as object detection, image processing, and pattern recognition. ALPR is also known as automatic vehicle identification, car plate recognition, automatic number plate recognition, and optical character recognition (OCR) for cars. The variations of the plate types or environments cause challenges in the detection and recognition of license plates. They are summarized as follows.

1) Plate variations:
   a) Location: plates exist in different locations of an image;
   b) Quantity: an image may contain no or many plates;
   c) Size: plates may have different sizes due to the camera distance and the zoom factor;
   d) Color: plates may have various characters and background colors due to different plate types or capturing devices;
   e) Font: plates of different nations may be written in different fonts and language;
   f) Occlusion: plates may be obscured by dirt;
   g) Inclination: plates may be tilted;
   h) Other: in addition to characters, a plate may contain frames and screws.

2) Environment variations:
   a) Illumination: input images may have different types of illumination, mainly due to environmental lighting and vehicle headlights;
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b) Background: the image background may contain patterns similar to plates, such as numbers stamped on a vehicle, bumper with vertical patterns, and textured floors.

The ALPR system that extracts a license plate number from a given image can be composed of four stages [5]. The First stage is to acquire the car image using a camera [6]. The parameters of the camera, such as the type of camera, camera resolution, shutter speed, orientation, and light, have to be considered. The second stage is to extract the license plate from the image based on some features, such as the boundary, the color, or the existence of the characters. The third stage is to segment the license plate and extract the characters by projecting their color information, labeling them, or matching their positions with templates. The final stage is to recognize the extracted characters by template matching or using classifiers, such as neural networks and fuzzy classifiers. Fig. 1 shows the structure of the ALPR process.

II. License Plate Extraction

The license plate extraction stage influences the accuracy of an ALPR system [7]. The input to this stage is a car image, and the output is a portion of the image containing the potential license plate. In the following are categorize the existing license plate extraction methods based on the features they used.

A. License Plate Extraction Using Boundary/Edge Information

The license plate normally has a rectangular shape with a known aspect ratio; it can be extracted by finding all possible rectangles in the image [7]. Edge detection methods are commonly used to find these rectangles. Sobel filter is used to detect edges. The edges are two horizontal lines when performing horizontal edge detection, two vertical lines when performing vertical edge detection, and a complete rectangle when performing both at the same time.

Boundary-based extraction that uses Hough transform (HT). It detects straight lines in the image to locate the license plate. The Hough transform has the advantage of detecting straight lines with up to 30° inclination. However, the Hough transform is a time and memory consuming process. a boundary line-based method combining the HT and contour algorithm is presented. It achieved extraction results of 98.8%. The generalized symmetry transform (GST) is used to extract the license plate. After getting edges, the image is scanned in the selective directions to detect corners.

B. License Plate Extraction Using Global Image Information

Connected component analysis (CCA) is an important technique in binary image processing. It scans a binary image [6] and labels its pixels into components based on pixel connectivity. Spatial measurements, such as area and aspect ratio, are commonly used for license plate extraction [7] applied CCA on low resolution video.

C. License Plate Extraction Using Texture Features
This kind of method depends on the presence of characters in the license plate, which results in significant change in the grey-scale level between characters color and license plate background color. The vector quantization (VQ) is used to locate the text in the image. VQ representation can gives some hints about the contents of image regions, as higher contrast and more details are mapped by smaller. The change of the grey-scale level results in a number of peaks in the scan line.

D. License Plate Extraction Using Color Feature

Some countries have specific colors for their license plates; some reported work involves the extraction of license plates by locating their colors in the image [6]. The basic idea is that the color combination of a plate and characters is unique, and this combination occurs almost only in a plate region. According to the specific formats of Chinese license plates, Shi et al. proposed that all the pixels in the input image are classified using the hue, lightness, and saturation (HLS) [10]-[13] color model into 13 categories a neural network is used to classify the color of each pixel after converting the RGB image into HLS. Neural network outputs, green, red, and white are the license plate colors in Korea. The same license plate color is projected vertically and horizontally to determine the highest color density region that is the license plate region. Since only four colors (white, black, red, and green) [14]-[17] are utilized in the license plates, the color edge detector focuses only on three kinds of edges (i.e., black–white, red–white and green–white edges).

TABLE I
Pros and Cons of Each Class of License Plate Extraction Methods [7]

<table>
<thead>
<tr>
<th>Methods</th>
<th>Rationale</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using boundary features</td>
<td>The boundary of license plate is rectangular</td>
<td>Simplest, fast and straightforward.</td>
<td>Hardly be applied to complex images since they are too sensitive to unwanted edges.</td>
</tr>
<tr>
<td>Using global image features</td>
<td>Find a connected object whose dimension is like a License plate.</td>
<td>Straightforward, independent of the license plate position</td>
<td>May generate broken objects</td>
</tr>
<tr>
<td>Using texture features</td>
<td>Frequent color transition on License plate.</td>
<td>Be able to detect even if the boundary is deformed.</td>
<td>Computationally complex when there are many edges</td>
</tr>
<tr>
<td>Using color features</td>
<td>Specific color on license Plate.</td>
<td>Be able to detect inclined and deformed License plates.</td>
<td>RGB is limited to illumination condition, HLS is sensitive to noise</td>
</tr>
<tr>
<td>Using character features</td>
<td>There must be characters on the license plate</td>
<td>Robust to rotation</td>
<td>Time consuming (processing all binary objects), produce detection errors when other text in the image</td>
</tr>
</tbody>
</table>

E. License Plate Extraction Using Character Features

License plate extraction [7] methods based on locating its Characters. These methods examine the image for the presence of characters. If the characters are found, their region is extracted as the license plate region.
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Instead of using properties of the license plate directly, the algorithm tries to find all character-like regions in the image [6]. This is achieved by using a region-based approach. The approach used is to horizontally scan the image, looking for repeating contrast changes on a scale of 15 pixels or more. It assumes that the contrast between the characters and the background is sufficiently good and there are at least three to four characters whose minimum vertical size is 15 pixels.

III. License Plate Segmentation

The isolated license plate is then segmented to extract the characters for recognition. An extracted license plate from the previous stage may have some problems [18]-[22], such as tilt and non-uniform brightness. The segmentation [8] algorithms should overcome all of these problems in a preprocessing step. The bilinear transformation is used to map the tilted extracted license plate to a straight rectangle. A least-squares method is used to treat horizontal tilt and vertical tilt in license plate images. Choosing an appropriate threshold for the binarization of the extracted license plate results in joined characters. These characters make the segmentation very difficult. License plates with a surrounding frame are also difficult to segment since after binarization, some characters may be joined with the frame. Enhancing the image quality before binarization helps in choosing the appropriate threshold. Techniques commonly used to enhance the license plate image are noise removal.

A. License Plate Segmentation Using Pixel Connectivity

Segmentation is performed by labelling the connected pixels in the binary license plate image. The labelled pixels are analyzed and those which have the same size and aspect ratio of the characters are considered as license plate characters.

B. License Plate Segmentation Using Projection Profiles

Characters and license plate backgrounds have different colors, they have opposite binary values in the binary image. Therefore, some proposed methods as in project the binary extracted license plate vertically to determine the starting and the ending positions of the characters, and then project the extracted characters horizontally to extract each character alone. Along with noise removal and character sequence analysis, vertical projection is used to extract the characters. By examining more than 30000 images, this method reached the accuracy rate of 99.2% with a 10–20 ms processing speed. Character color information is used in the projection instead of using the binary license plate.

C. License Plate Segmentation Using Prior Knowledge of Characters

Prior knowledge of characters can help the segmentation of the license plate. The binary image is scanned by a horizontal line to find the starting and ending positions of the characters. When the ratio between characters pixels to background pixels in this line exceeds a certain threshold after being lower than this threshold, this is considered as the starting position of the characters. The opposite is done to find the ending position of the characters.

D. License Plate Segmentation Using Character Contours

Contour modelling is also employed for character segmentation. A shape driven active contour model is established, which utilizes a variation fast marching a The system works in two steps. First, rough location of each character is found by an ordinary fast marching technique combined with a gradient-dependent and curvature dependent speed function. Then, the exact boundaries are obtained by a special fast marching method.

E. License Plate Segmentation Using Combined Features

In order to efficiently segment the license plate, two or more features of the characters can be used. An adaptive morphology based segmentation approach for seriously degraded plate images was proposed. An algorithm based on the histogram detects fragments and merges these fragments. A morphological thickening algorithm locates reference lines for separating the overlapped characters. A morphological thinning algorithm and the segmentation cost calculation determine the baseline for segmenting the connected characters.

TABLE II

Pros and Cons of Each Class of License Plate Segmentation Methods [8]
Methods | Pros | Cons
--- | --- | ---
Using pixel connectivity | Simple and straightforward, robust to the license plate rotation. | Fails to extract all the characters when there are joined or broken characters.
Using projection profiles | Independent of character positions, be able to deal with some rotation. | Noise affects the projection value, requires prior Knowledge of the number of license plate characters.
Using prior knowledge of characters | Simple. | Limited by the prior knowledge, any change may Result in errors.
Using character contours | Can get exact character boundaries | Slow and may generate incomplete or distorted contour.
Using combined features | More reliable. | Computationally complex.

IV. Character Recognition

The extracted characters are then recognized and the output is the license plate number. Character recognition [23]-[24] in ALPR Systems may have some difficulties. Due to the camera zoom factor, the extracted characters do not have the same size and the same thickness. Resizing the characters into One size before recognition helps overcome this problem. The characters’ font is not the same all the time since different countries’ license plates use different fonts. Extracted characters [7] may have some noise or they may be broken. The extracted characters may also be tilted. In the following, we categorize the existing character recognition methods based on the features they used.

A. Character Recognition Using Raw Data

Template matching is a simple and straightforward method

In recognition. The similarity between a character and the templates is measured. The template that is the most similar to the character is recognized as the target. Most template matching methods use binary images because the grey-scale is changed due to any change in the lighting. Each template scans the character column by column to calculate the normalized cross correlation. If a character is different from the template due to any font change, rotation, or noise, the template matching produces incorrect recognition. The problem of recognizing tilted characters is solved by storing several templates of the same character with different inclination angles.

B. Character Recognition Using Extracted Features

All character pixels do not have the same importance in distinguishing the character, a feature extraction technique that extracts[7] some features from the character is a good alternative to the grey-level template matching technique. It reduces the processing time for template matching because not all pixels are involved. It also overcomes template matching problems if the features are strong enough to distinguish characters under any distortion. The extracted features form a feature vector which is compared with the pre-stored feature vectors to measure the similarity. The feature vector is generated by projecting the binary character horizontally and vertically the feature vector is generated by dividing the binary character into blocks of 3×3 pixels. Then, the number of black pixels in each block is counted. The feature vector is generated by dividing the binary character after a thinning operation into 3 × 3 blocks and counting the number of elements that have 0°, 45°, 90°, and 135° inclination. the character is scanned along a central axis. This central axis is the connection between the upper bound horizontal central moment and lower bound horizontal central moment.

TABLE III
Pros and Cons of Each Class of Character Recognition Methods [9]
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<table>
<thead>
<tr>
<th>Methods</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using pixel values</td>
<td>Template matching</td>
<td>Simple and straightforward</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processing non important pixels and slow, vulnerable to any font change, rotation, noise and thickness Change.</td>
</tr>
<tr>
<td></td>
<td>Several templates for each character</td>
<td>Be able to recognize tilted characters</td>
</tr>
<tr>
<td>Using extracted features</td>
<td>Horizontal and vertical projections</td>
<td>Be able to extract salient features, robust to any distortion, fast recognition since the number of features is smaller than that of the pixels.</td>
</tr>
<tr>
<td></td>
<td>Hotelling transform</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The number of black pixels in each 3 x 3 pixels block</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Count the number of elements that have certain degrees inclination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The number of transitions from character to background and spacing between them</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sampling the character contour all around</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gabor filter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kirsch edge detection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Convert the direction of the character strokes into one code</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pixels’ values of 11 sub blocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non overlapping 5 x 5 blocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contour-crossing counts (CCs), directional counts (DCs), and peripheral background area (PBA)</td>
<td></td>
</tr>
</tbody>
</table>

V. Future Directions, and Conclusion

**Current Trends and Future Directions**

Although significant progress of ALPR techniques has been made in the last few decades, there is still a lot of work to be done since a robust system should work effectively under a variety of environmental conditions and plate conditions. An effective ALPR system should have the ability to deal with multistyle plates, e.g., different national plates with different fonts and different syntax. Little existing research has addressed this issue, but still has some constraints. Four critical factors were proposed to deal with the multistyle plate problem: plate rotation angle, character line number, the alphanumeric types used and character formats[25]-[29].

Experimental results showed 90% overall success in a data set of 16 800 images. The optical character recognition is managed by a hybrid strategy. An efficient probabilistic edit distance is used for providing an explicit video-based ALPR. Cognitive loops are introduced at critical stages of the algorithm. In most ALPR systems, either the acquisition devices provide still images only, or only some frames of the image sequence are captured and analyzed independently. However, taking advantage of the temporal information of a video can highly improve the system performance. Basically, using the temporal information consists of tracking vehicles over time to estimate the license plate motions and thus to make the Recognition step more efficient. There are two kinds of strategies to achieve that goal. One strategy is using the tracking output to form a high resolution image by combining multiple, subpixel shifted, low-resolution images. This technique is known as super-resolution reconstruction and to track it using a data-association approach.
Proposed a new reduced cost function to produce images of higher resolution from low resolution frame sequences. It can be employed for real-time processing. Alternative to super-resolution techniques, we can merge the high-level outputs of the recognition to make a final decision.

The resolution of current ALPR video cameras is low. Recently, high-definition cameras are adopted in license plate recognition systems since these cameras preserve object details at a longer distance from the camera. However, due to the large amount of information to be processed, the computational costs are high. To address this issue, introduced a scanning method, operator context scanning (OCS), which uses pixel operators in the form of a sliding window, associating a pixel and its neighbourhood to the possibility of belonging to the object that the method is searching. Segmentation and recognition [8]-[9] are two important tasks in ALPR. Traditionally, these two tasks were implemented in a cascade fashion independently and sequentially. Recently, there has been an increasing interest in exploring the interaction between the two tasks. Recently, license plate recognition has also been used for vehicle manufacturer and model there are many other open issues for the future research.

1) The technical specifications of video surveillance equipment vary as older systems may be equipped with low resolution black and white cameras, and newer systems are likely to be equipped with high resolution color cameras. An effective ALPR system should be able to integrate with varying existing surveillance equipment.

2) For video-based ALPR, we need to first extract the frames that have the passing cars. It needs either frame differencing or motion detection. Extracting the correct frame with a clear car plate image is another challenge, especially when the car speed is very fast, violating the speed limit.

3) To deal with the illumination problem, good preprocessing methods (image enhancement) should be used to remove the influence of lighting and to make the license plate salient.

4) New sensing systems those are robust to the change of illumination conditions should also be used to elevate the ALPR performance.

5) For optical character recognition, future research should concentrate on improving the recognition rate on ambiguous characters, such as (B-8), (O-0), (I-1), (A-4), (C-G), (D-O), (K-X), and broken characters.

6) To evaluate the performance of different ALPR systems, a uniform evaluation way is needed. Besides a common test set, we also need to set some regulations for performance comparison, such as how to define the correct extraction of license plate, what is the successful segmentation, how to calculate the character recognition rate.

7) The proposed LPR algorithm consists of two modules, one for locating license plates and one for identifying license numbers. Soft computing techniques rooted in fuzzy (for license plate location) and neural (for license number identification) disciplines were introduced to compensate for uncertainties caused by noise, measurement error and imperfect processing.

VI. Conclusion
This paper presented a comprehensive survey on existing a real time ALPR techniques by categorizing them according to the features used in each stage. An LPR system consists of four processing stages. In the image acquisition stage, in the license plate extraction stage, the license plate is extracted based on some features such as the colour, the boundary, or the existence of the characters. In the license plate segmentation stage, the characters are extracted by projecting their colour information, by labelling them, or by matching their positions with template. Finally, the characters are recognized in the character recognition stage by template matching, or by Classifiers such as neural networks and fuzzy classifiers. The future research of ALPR should concentrate on multistyle plate recognition, video-based ALPR using temporal information, multiplates processing, high definition plate image processing, ambiguous-character recognition, and so on.

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