Automatic License Plate Recognition: a Review

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Abstract

In recent years, many researches on Intelligent Transportation Systems (ITS) have been reported. Automatic License Plate Recognition (ALPR) is one form of ITS technology that not only recognizes and counts vehicles, but distinguishes each as unique by recognizing and recording the license plate's characters. This paper discusses the main techniques of ALPR. Several open problems are proposed at the end of the paper for future research.

Keywords: localization, character recognition, skews detection, color information

1. Introduction

In recent years, many researches on Intelligent Transportation Systems (ITS) have been reported. As one form of ITS technology, Automatic License plate Recognition (ALPR) not only recognizes and counts vehicles, but distinguishes each as unique by recognizing the characters in the license plates. In the approach, a camera captures the vehicle images and a computer processes the captured images and recognizes the information on the license plate by applying various image processing and optical pattern recognition techniques [1]. The significant advantage of the ALPR system is that it assumes that all vehicles already have the unique identification (the license plate). So, no additional transmitter or responder is required to be installed on the vehicle.

Computer-based license plate recognition emerged in the 1980's. Currently, there are multiple commercial license plate recognition systems available [2, 3]. ALPR plays an important role in numerous applications. Examples are [1]:

- Border crossing control
- Identification of stolen vehicles
- Automated parking attendant
- Petrol station forecourt surveillance
- Red light camera
- Speed enforcement
- Security
- Customer identification
- Indoor parking lots/Underground parking

One of the key points for most of the traffic related applications, such as road traffic monitoring or parking lots access control, is the possibility to automatically detect and recognize vehicle license plate in uncontrolled open environments [4].

Due to different working environments, ALPR techniques vary from application to application [5]. Although ALPR is a well developed technology, there are, however, still many problems needed to be solved.

In this paper, main techniques of ALPR are analysed and compared in section 2. In section 3, several open problems in this area are proposed for future research.

2. Main Techniques

Generally, ALPR systems are composed of two units: an *image acquisition unit* (e.g., a camera) and the *image analysis unit* (general purpose computing device). The image acquisition unit is situated over a pole focusing on the adjacent road lane or installed above the vehicle lane targeting the incoming vehicles so as to capture their images. The acquired images are properly transferred to the image analysis unit for processing and analyzing.

In this paper, a four-task module is defined to illustrate the license plate recognition system: 1) image acquisition, 2) license plate localization, 3) character isolation, and 4) character recognition, as shown in Figure 1.

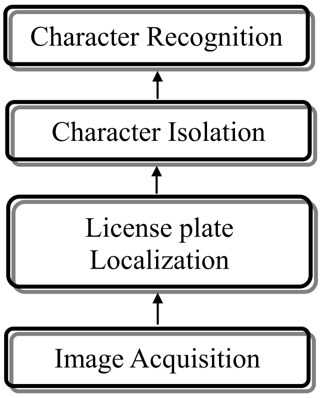

Figure 1. System architecture

The four tasks mentioned above may be modified in order to make the overall algorithm more robust to adapt the environmental differences for different applications. For example, some tasks may be removed. However, by doing so, it becomes a simple thing to illustrate the main techniques and the open problems for ALPR system, and the flexibility of the recognition system is maximized.

In the following, the main techniques used for each tasks of ALPR are discussed and compared.

2.1 Image Acquisition

License plate recognition is realized by acquiring images with a sensing system and then by image processing algorithm for identification. The performance of LPR system is determined by the quality of acquired images. So, the image acquisition is a crucial step, which relates to how to acquire high quality vehicle images under various conditions.

2.1.1 Two Approaches for Image Acquisition. There are two broad categories of approaches for image acquisition: triggered approach and non-triggered approach.

Most existing license plate recognition systems use triggered approach, where hardware (e.g., an inductive loop sensor within the vehicle lane) is used to indicate when the image should be captured, which in turn triggers the license plate recognition process. Triggered approach suffers from several drawbacks [6]. Firstly, the positioning of the external sensors may be difficult. Secondly, the triggering hardware would introduce additional cost to the system. Thirdly, the acquired images may not be appropriate for recognition when the license plate is partially out of the camera field of view.

In the non-triggered approach, the camera continues capturing images at a predefined frame rate as long as the system is activated. The system software needs to deal with the entire video sequence to find if there exists a vehicle in a certain frame. Then, the recognition process is triggered by the internal signal that a vehicle is detected in the input video sequence rather than by an external signal produced by triggering device. This approach does not require any triggering hardware. Usually, pixel differencing algorithm is used to detect the presence of vehicle. However, the pixel differencing is generally a very computational expensive task. So, fast algorithms are needed in order to extract the regions which are more likely to contain the license plate. Low resolution–based processing is carried out to solve the problem in [6].

2.1.2 Sensing System. No matter what approach is used to acquire vehicle images, the sensing system for capturing images plays a significant role in the overall system. However, the insufficiency of dynamic range of conventional cameras is a serious problem in realizing a robust vision system for ALPR because road scenes, where most ALPR systems work, have a wide dynamic range of brightness if no special illuminators are adopted. There exist two approaches to solve the problem: one is to improve imaging devices themselves, and the other is to apply image processing algorithm. Some imaging devices have been developed for the former approach [7]. However, no device has been realized that satisfies the requirements for the vehicle applications, such as a wide dynamic range, enough resolution, sensitivity, frame rate, and cost. On the other hand, several studies by the latter approach have been reported [8]. These studies indicate that an image with a wider dynamic range than that of a camera can be obtained by combining the images taken under different exposure conditions.

In order to avoid blurring of images against fast moving vehicles, generally, a high speed shutter video camera is needed. Moreover, image processing method can be utilized as well to avoid the possible cost introduced by installing high performance video cameras [8].

2.2 License plate Localization

Prior to the character recognition, the license plates must be located from the background vehicle images. This task is considered as the most crucial step in the ALPR system, which influences the overall accuracy and processing speed of the whole system significantly. Since there are problems such as poor image quality due to various ambient lighting conditions, image perspective distortion resulted mainly from various combination of visual angles between the camera and the vehicles, other disturbance characters or reflection on vehicle surface which would influence license plate localization, and the color similarity between the license plate and background vehicle body, the license plate is often difficult to be located accurately and efficiently.

Many methods have been proposed to segment the license plate from the car images. In this paper, these methods are grouped into several classes according to the features that are used to locate the license plate. The major features used for license plate detection include texture, vertical edges, color, symmetry, and so forth. In the following, four kinds of license plate localization methods are discussed and compared. They are texture-based methods, vertical edges-based methods, and color-based methods. After this, skew correction of the license plate is discussed as well.

2.2.1 Texture-based License plate localization. The main idea of the texture-based methods is based on the consideration that, the characters in the license plate always have a distinctive grey level to the background of the license plate, which indicates following important properties that can be utilized to locate the character regions:

1) The area of license plate always has a relatively higher contrast in the car image;

2) The grey level changes are more frequent in the license plate area, which in turn results in strong grey level variations and high density of edges, especially vertical edges;

3) If a candidate area indeed contains a plate, the foreground pixels are distributed evenly comparing to the areas with simple structures.

Many typical methods based on the idea are proposed in references by detecting high contrast [9]. Due to the difference of illumination conditions, in order to make the algorithm much more robust, the gradient information of the grey level images is used, e.g., high local variances [1, 10, 11], high edge density [12] and high spatial frequencies [13].

In this kind of methods, in order to make the final decision, some prior knowledge, such as aspect ratio (the height to width ratio of the license plate), the area (the number of pixels in the region), the orientation of the license plate, the density of the region (the ratio between the black regions and the area of the bounding rectangle), and the proximity to the image frame (the distance between the pixels of the region and the image frame) are often combined using their weighed sum. Generally, this kind of methods also needs some morphological operations to remove the noise as possible as it can or to merge several adjacent regions of a license plate which are separated during binarization.

Although this kind of methods shows good performance in dealing with boundary deformation, they show weakness for an image with non-plate regions, which have similar evenly distributed grey value difference to the license plate area such as disturbing characters and a radiator region. In this case, even though prior knowledge of the license plate is combined, it still cannot locate the license plate region exactly. Moreover, the intensity differences between the extracted license plate and car colours are not stable at different changes of lighting conditions and view orientations.

2.2.2 Vertical lines-based License plate localization. The second class is based on line detection. It is observed that most of the vehicles usually have more horizontal lines than vertical lines. If frames of the license plate are detected correctly, four corners of the license plate can then be located. Generally, to reduce the complexity of algorithm, the vertical edges are detected. After this, the morphological operation is applied to remove unwanted objects that do not satisfy some specific features. Then, the aspect ratio of license plate is used to match the vertical edges to find the region of probable license plates [14]. In order to detect the lines in the license plate, Hough Transform (HT) is widely used [15-17].

This kind of methods is normally simple and fast and is not easily interfered by other character regions only if there are not clear frames around them. However, the drawback is that, it is too sensitive to the unwanted edges, which may happen to appear in the front side of a car. Therefore, this kind of methods cannot be used independently. Moreover, the basic assumption of this kind of methods is that only the license plate has vertical frames in a vehicle image. This assumption may not be true where many vehicle images have vertical edges from a radiator and there are more than one vehicle images captured in a single frame image. Regarding using the HT for detecting lines in binary images, it gives positive effect on images with a large plate region where it can be assumed the shape of license plate is defined by line. However, HT is very sensitive to deformation of a plate boundary. Furthermore, HT inherently needs a large memory space and considerable amount of computing time.

2.2.3 Color-based License plate localization. The third attempt is to overcome the previous shortcomings by analyzing color information. Rather than using a grey value, the idea is to use a unique color or color sequence of the license plate region. License plates have been appointed different colors in their background and foreground characters which can be utilized to distinguish the license plate area from the car images. Especially, in some places, color combination of a plate and character is unique and this combination occurs only in a plate region. This color difference information and the sequence of color in the scanning lines of license plate area from other areas can be utilized as the important features to locate the license plate.

Generally, before classifying colors, RGB format is converted to HIS model, because the HIS model can provide higher correct rate of classification than the RGB model. While how to acquire the color of a certain pixel is a difficult thing. Neural network classifier is usually used to classify colors of pixels [18, 19]. Then, the color sequence codes of license plate within scanning line of the cross section of the license plate from left to right are extracted as the features of license plate. Based on these features, leaning-based methods are used to extract the license plate area, which include standard back propagation neural network (BPNN) [20], distributed genetic algorithm [21].

This kind of method overcomes the previous shortcomings by analyzing color information. However, it is still a very difficult thing by using the color information only to extract a specific object from an image if vehicles may have similar color to the background of license plate, and, most importantly, colors of license plates in images vary greatly due to different light conditions under which the images were taken and fading of color which appear to be unevenly coloured. Thus, it is not easy to segment license plate directly by using information on plate's colors. Additionally, as we discussed before, because color image processing is mostly based on learning-based classification methods, it usually takes longer time than grey-level image processing.

2.2.4 Skew Detection of License plate. Besides the license plate localization, in a real ALPR system, the car image may appear tilted due to the perspective distortion and uneven or curvy road surface. It is difficult for conventional license plate detection and recognition methods to recognize the license plate with large pan and title angles. So, the skew should be corrected as early as possible. If the license plate is detected using Hough transform-based line detection method, then, the skew angle can be detected at the same time which can be utilized to correct the skewed license plate and characters [25]. Also the skew can be geometrically corrected using certain transformation [13, 26]. Wang [10] proposed to use major axis to normalize the character to the same orientation.

2.3 Character Isolation

Before the character recognition processing, individual character images need to be isolated or segmented from the extracted license plate image. This step is not necessary in some non-segmented recognition approaches. Various approaches have been proposed in the literature. The simplest method is based on vertical projections of binarized license plate image [14, 27, 28]. Projection-based method is simple and fast to isolate each character images. However, a change of camera position with respect to vehicles will cause perspective distortion of the plate in the image, and both vertical and horizontal axes of the image do not coincide with those changes of the plates. So, the projection-based approach does not work well on the image with tilted license plate and those license plates that consist of more than one row. Region analysis-based is another kind of popular method used to segment the characters which overcome the drawback of the projection-based isolation method [10].

2.4 Character Recognition

Recognition of characters is the last step in the ALPR system. A wide variety of Optical Character Recognition (OCR) methods have been considered for individual character recognition. These methods can be broadly classified into matching-based methods and learning-based methods.

A straightforward method for character recognition or classification is to use template matching [14, 27, 29]. In the case of the standard template matching algorithm, template images of each character in each font that become the references for the comparison are created and stored in a database in advance. Then, a continuous search is made by the template matching method to find whether a similar image exists within the search area. Generally, to make the template matching usable in real practice, the size of the candidate images is normalized to a predefined dimension, which is exactly the same with that of the template images. In this case, template matchers usually treat all pixels equally. Changes in pixel values, if compared with the prototypes, will all contribute the same to the significance of the pixel. This algorithm, however, often leads to detection error and misrecognition if the color and the brightness of the objects changes in the external illumination conditions for different applications. Rather than compare the character images themselves, other features are used for template matching. For example, using the comparison between the Hotelling transformed counterparts and the Hotelling transformed prototypes [13], using the linear sum of intensity projection and intensity variance of projection direction [30], and using histograms as features [28].

Besides the matching-based method, many learning-based methods are widely used popularly as well, such as multilayer neural network [22]. Support Vector Machine (SVM) [30], RULES-3 inductive learning algorithm and template matching technique [31].

There is a tradeoff between these two groups of approaches: learning-based methods can generally achieve relatively better accuracy, but at the cost of increased time complexity. Moreover, when a learning-based algorithm is used to classify, in order to both improve the speed of the classifier and make a better result, a proper feature is needed to be extracted from the input matrix. In [16] and [11] Fourier shape descriptors were used to descript each candidate character's boundary, and then, those values are input to the neural network for recognition.

3. Main problems

ALPR is not a new topic. Although numerous methods have been proposed, the problem is however not be solved thoroughly. Ideally, the image acquisition must be able to obtain the best contrast between plate background and characters in as wide a range of styles as possible, and each algorithm in the recognition chain should be able, as humans eyes are, to find the plate, recognize what is relevant and important, and complete the recognition, reassessing if something doesn't seem quite right [32]. For future research work, several open problems are proposed here.

3.1 Robust Vision System

Of the various working conditions, outdoor scenes and non-stationary backgrounds may be the two factors that most influence the quality of images acquired and in turn the complexity of the techniques needed [5]. Appropriate camera equipment and settings (optics, shutter speed, aperture, camera positioning and angle) are needed to capture non-blurred images against quickly passing vehicles and capable of capturing fine images under greatly varied illumination conditions from twilight up to noon in the sunshine. Another difficulty is caused by the extremely poor quality of some plates. Such plates can have holes, can be dirty, can have other signs attached on their surface, etc.

3.2 Recognition Color License Plates

In some places, the foreground color and the background color of different license plates may be different and different color combinations denote for different type of vehicles or originating places of the vehicles. So, one of the most important features which consist of more information than characters in the license plates themselves only is the color and its combination sequence information. However, currently proposed color-based ALPR systems can only process one or sometimes two kinds of colored number pates. Moreover, in some countries, personalized license plates are allowed to use, where different color combinations are selectable and certain color combination may not possess the strongest contrast within the vehicle images. Making used of the color information in the license plate rather than grey-level information only is one the key interest points for the future research.

3.3 Robust Recognition Algorithm

Recognition algorithms of ALPR designed to operate in the real world must deal with a series of degradations and complications. In some cases, there are more than one row main parts in the license plates which makes the recognition algorithms more complicated. Other icons (dots, dashes, badges etc.) are often found in any position within the normal alphanumeric sequence. In some cases, plates are simple but the surrounding information can cause confuse [32]. Moreover, camera deployment and shutter speed can add further variability to all plate due to geometric distortion and speed blur. All these factors make the requirement for a robust recognition algorithm. Beside these, nearly all customers require the ability to read licence plates from more than one country of origin, and this poses a considerable challenge to the developer in maintaining high recognition accuracy over a wide diversity of plate styles.

3.4 Test Bed

In this paper, we do not touch the correct localization rate or recognition rate and processing time, because for different ALPR applications, although much of the basic processing remains the same, there may be great environmental differences making the algorithms incomparable. So, in order to evaluate the performance of different methods fairly, a test bed needs to be developed that could easily be adapted and allow different algorithms to be tested.

4. Conclusion

ALPR plays an important role in numerous applications and a number of techniques have been proposed. In this paper, we reviewed the major techniques used in ALPR technologies and proposed several open problems for future research. The whole system is divided into four tasks: image acquisition, license plate localization, character isolation, and character recognition. Among them, a robust vision system and a robust recognition algorithm still need to be improved. Moreover, vehicle color recognition is also of interest to some customers as a further verification of the vehicle. Enhancements to the basic system are now technically feasible, for example providing a compressed image with time stamp for each plate entry in the vehicle log and providing a database in order to search the information of the recognized license plate.

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