Proceedings of the 2023 International Conference on Software Engineering and Machine Learning
DOI: 10.54254/2755-2721/8/20230257

Studies advanced in license plate recognition

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Abstract. License plate recognition is a crucial mission in computer vision, and deep learning has significantly improved its performance. A representative license plate recognition system involves five components: license plate image preprocessing, image acquisition, license plate detection, character recognition, and character segmentation. This paper will explore the methods commonly used in each stage of the recognition process and analyze some of the current challenges and future trends of license plate recognition. This discussion will consider real-world factors such as lighting and weather conditions that can affect recognition accuracy. Ultimately, it is hoped that these insights will contribute to the development of intelligent transportation systems.

Keywords: license plate recognition, automatic recognition, license plate positioning, character recognition, character segmentation.

1. Introduction

With the increasing industrialization and rising living standards, cars have become the primary mode of transportation for daily travel. As the number of vehicles continues to grow, traffic problems such as congestion and environmental deterioration have become increasingly serious, making the modernization of urban traffic management and the development of intelligent highways imperative for sustainable urban development [1]. High-tech solutions are needed to improve traffic management intensity and level, and as a result, the development of smart cities has become a trend.

Automatic license plate recognition technology has significant application value in public safety and traffic management and plays a crucial role in achieving national traffic modernization [2]. During these years, license plate recognition systems have been extensively used in vehicle management, information collection, and traffic safety prevention in related industries [3]. Using digital image processing, pattern recognition, and computer vision technology, license plate recognition is capable of accurately and quickly obtaining the digital information of a vehicle without affecting its driving, leading to intelligent vehicle management.

The license plate recognition system is a computer vision system that collects car images using monitoring equipment or cameras and recognizes the characters on the license plate through pattern recognition. The complete process involves automatic location of the license plate image from the collected vehicle image, segmentation of each character on the license plate from the located image, and accurate identification of Chinese characters, letters, and numbers using pattern recognition technology. This process ultimately leads to intelligent monitoring and management of vehicles. Thus,

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the license plate recognition process includes preprocessing the collected image to remove interference, locating the license plate image from the vehicle image, segmenting the located license plate image into individual characters, recognizing each segmented character, and synthesizing them into a complete license plate number. A flow chart of this process is displayed in Figure 1.

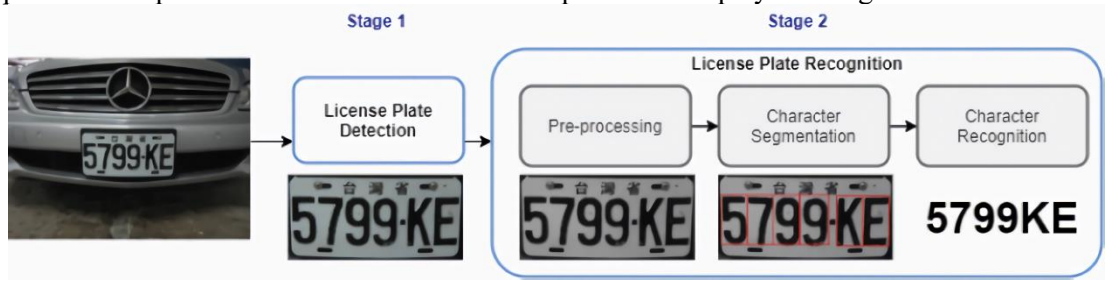

Figure 1. License plate recognition flow chart.

2. License plate recognition approaches

2.1. License plate image preprocessing

License plate images are typically captured using a camera, but the acquired images may be impacted by external elements such as lighting, shooting angle, and shadows, resulting in various forms of interference that can affect license plate recognition accuracy [4]. Preprocessing is required to address this issue, which includes various image processing techniques such as grayscale conversion, grayscale stretching, contrast enhancement, image binarization, image rotation, and filtering smoothing to remove interference information and improve image quality for better recognition performance.

It is possible to transform the mysterious color license plate photos into a three-dimensional matrix made up of the three primary hues red, green, and blue. This means that each component value of these colors, which range from 0 to 255, can represent any pixel in the image. Hence, each pixel has around 16 million colors. (256 x 256 x 256), whereas grayscale images require only one channel to represent the color data. Therefore, when processing on a computer, the data processing volume can be reduced by 67% compared to RGB images, resulting in an effective improvement in processing speed. The three weighted average methods of RGB are commonly used to convert RGB images into grayscale images. The formula for this conversion is as follows:

$$I = 0.229R + 0.587G + 0.114B \quad (1)$$

2.2. License plate detection

License plate detection is the process of distinguishing the license plate area from a complex and complete image of a vehicle and accurately locating the license plate area [5]. It is the first step in the license plate recognition system. Common positioning algorithms used in license plate detection include feature-based algorithms such as color and edge features, algorithms based on mathematical morphology, and machine learning-based algorithms for instance for support vector machines, wavelet transforms, and neural networks. Figure 2 shows the taxonomy of license plate detection techniques used in the current method.

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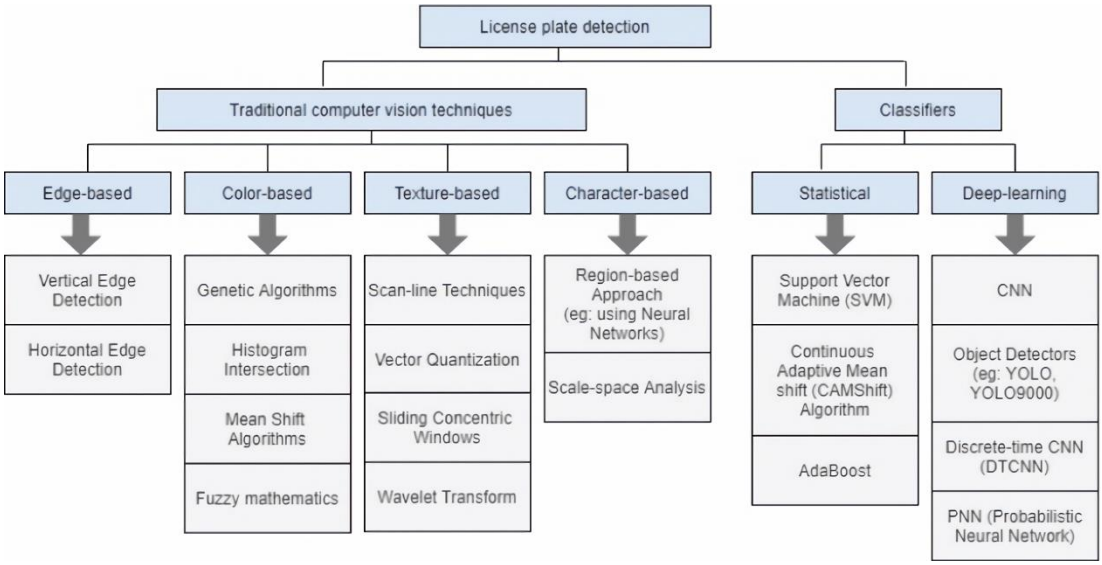

Figure 2. Classification of license plate detection techniques.

2.2.1. Edge-based methods. Edge detection is a valuable technique in image processing and computer vision that leverages the contrast of pixels within an image to identify the boundaries or edges within it [6]. This approach is typically employed in areas where there is a significant change in grayscale among the pixels in a particular local area of the image. In my country, license plates typically consist of white characters on a blue background, black characters on a yellow background, or black characters on a white background [7]. These plates often contain a combination of letters and numbers, and the edges of the characters exhibit distinct texture features. To identify the license plate within an image, the edge detection method can be utilized to highlight the license plate area. There are several normally used edge detection operators, including Roberts, Sobel, Prewitt, and Canny. These operators enable the extraction of relevant image features and the identification of the edges within an image, ultimately facilitating more accurate and efficient image analysis and processing.

2.2.2. Colour-based methods. The license plate detection and positioning method is typically based on the characters within the license plate and the color of the license plate's background [8]. As most license plate images are collected in RGB format, where each color component is between 0 and 255 and the correlation between the three colors is strong, it can be difficult to precisely locate the license plate. Therefore, the RGB space is usually transformed into the HSV space, where H represents the hue component, S represents the saturation, and V represents the brightness.

By utilizing the relationship between the background color of the license plate and H, S, V, the background color image of the vehicle can be extracted and filtered to remove images of other colors. This approach significantly reduces the search region of the license plate within the image, improving detection and positioning accuracy.

However, this method has limitations when the tinct of the vehicle body or surrounding environment resembles the color of the license plate. Additionally, the accuracy of the color-based positioning approach can be affected by lighting conditions. In such cases, the positioning accuracy may be suboptimal, and the method may not yield satisfactory consequences.

2.2.3. Texture-based methods. Texture-based methods rely on the detection of characters on license plates take for a means of identifying them [9]. The approach is based on the observation that there is a considerable color contrast between the characters and the background of the plate, resulting in frequent color changes. As a result, when the image is converted to grayscale, the contrast between the characters and the background becomes even more pronounced, leading to a distinct pattern of pixel

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intensities around the plate. Furthermore, the color changes also result in an increased edge density in the border areas of the container.

2.2.4. Character-based methods. Another approach for license plate detection involves identifying and locating characters within an image, known as character-based methods [10]. These methods consider regions that contain characters as potential license plate regions.A technique to extract all character areas in an image that are similar was created by Matas and Zimmermann. Afterwards, these regions were classified using a neural network classifier; if a linear spatial arrangement was found, it was assumed to be a plausible license plate region. The technique reportedly has a 95% detection accuracy for license plates and is resistant to changes in illumination and viewing angles.

2.2.5. Using statistical classifiers. License plate detection has been addressed in several studies using cascaded classifiers trained with Haar-like features and adaptive boosting (AdaBoost). For instance, a decision tree-based cascade classifier was trained using AdaBoost, and the procedure was made simpler by combining statistical data with Haar-like features. A detection rate of 94.5% was attained using this enhanced method in a variety of lighting situations and viewing angles.

2.2.6. Deep learning based methods. Artificial Neural Networks (ANNs) is a computational model consist of an input layer, a hidden layer, and an output layer [11]. The input layer receives data inputs, which are then processed through the hidden layer to produce output in the output layer. During the training phase, ANNs learn to adjust the weights between the hidden layer nodes to produce accurate output through a process called backpropagation. One application of ANNs is in license plate recognition, where the network is trained on a large number of annotated images and corresponding recognition results. Through forward propagation and backpropagation, the network learns to automatically extract features from license plate images and map them to their corresponding outputs. Once trained, the network can be used to recognize and locate license plate areas in new images.

2.3. Character segmentation

Character segmentation is the course of dividing a license plate image into individual character images after it has been positioned in the previous step. This process relies on the binary image and separates characters based on their structural characteristics or pixel characteristics. License plate characters can be Chinese characters, letters, or numbers, and the primary methods used for character segmentation include the projection method, connected domain method, and static boundary method for each character.

2.3.1. Projection method. A common technique of character splitting is projection, and it is relatively simple to use. This is the precise procedure: The binary picture of the characters from the license plate is projected both horizontally and vertically using the features of the characters on the actual license plate. The beginning and finishing positions of the character height orientation are established using statistical values derived from the horizontal projection, which examines and counts the dark pixels in the character region from top to bottom. The beginning and finishing positions of the breadth orientation are determined by the statistical values derived from the vertical projection, which on the other hand counts and reads the dark pixels in the character area from left to right. To ultimately acquire the characters of the license plate and separate them from the license plate picture, the characters are segmented by finding the upper and lower borders as well as the right and left boundaries of each character.

2.3.2. Pixel connectivity. Each time the binary image containing N pixels is scanned, the number of black pixels is counted to determine the connected domain of the character. Generally, numbers and letters form a single connected domain, while Chinese characters are relatively complex and may form multiple connected domains, especially when they appear as the first character. Therefore, during the

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scanning process, the minimum bounding rectangle of the connected domain containing letters and numbers is usually found by cutting from right to left based on the characteristics of Chinese license plates. The remaining multiple connected domains are typically Chinese characters.

2.3.3. Using deep neural networks. Neural networks are a relatively new method for character segmentation, particularly when it comes to computer vision tasks. Convolutional neural networks (CNNs) have been certified to be effective in this area. By taking a license plate as input and using a CNN, a bounding box can be generated for each character as output. However, the execution of CNNs can be more time-consuming and resource-intensive than traditional computer vision techniques, depending on the dataset. As a consequence, some deep learning-based systems for reading license plates do not use explicit character segmentation in their later phases, instead relying on implicit character segmentation. This strategy can cut down on the process's processing requirements and component count.

2.4. Character recognition

In character recognition, each segmented character image is sent separately to a classifier, which uses pattern recognition methods to determine the category of each character. The characters are then combined in order from left to right to form the license plate number. There are several common methods used in character recognition, including matching characters with template libraries, counting character features, and machine learning methods like support vector machines and neural network recognition methods. These approaches can effectively identify characters and have been applied successfully in license plate recognition systems.

2.4.1. Template and pattern matching techniques. There are two common methods based on template matching: the gray value-based matching technique and the feature extraction-based template matching method. Many geometrical and morphological computations are required by the feature extraction-based technique, making the calculation process complex and unable to meet the real-time requirements of license plate recognition. As a result, this approach is rarely employed. The gray value-based technique needs a consistent template library but does not need feature extraction. The size of the character to be recognized is changed during recognition so that it is consistent with the size of the characters in the template library. The similarities between the character and the templates in the library are then assessed using a statistical approach, cosine similarity, or distance function. The character in the template library with the supreme similar characteristic value is the final recognition outcome.

This method is simple and can process multiple characters in parallel, but it is only suitable for characters with the same size and font as the template library. Otherwise, pre-processing is required, or the recognition accuracy may be low. Thin or blurred characters can also affect recognition accuracy. Moreover, normalized characters can cause character distortion. When the template library is large, recognition accuracy can improve, but matching and recognition speed may be slower.

2.4.2. Character recognition using feature extractors. The feature statistics-based recognition approach entails creating a feature vector based on each character's traits and creating a classifier utilizing several structural and statistical properties. External contour, internal structure, and stroke change aspects are among the statistical features. Before to entering the stated features into the classifier, it is important to minimize the dimensionality of the features due to the enormous amount of Chinese characters. The character characteristics are initially retrieved from the character pictures for recognition, then following processing and analysis, classification labels are created.

This recognition method is influenced by the accuracy of license plate segmentation and noise. For Chinese characters, due to the large amount of characteristic information, the calculation can be relatively large. However, this approach can effectively recognize characters with high accuracy and can be useful in license plate recognition systems.

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2.4.3. Character recognition using deep learning. Artificial neural networks with feature extraction and artificial neural networks without feature extraction make up the two categories of artificial neural network-based algorithms. The feature extraction neural network, as its name suggests, must first choose and extract character traits before using those features to train the neural network. The accuracy of the recognition results in hinges on the algorithm's choice of character features, and extracting character features will slow down the recognition process. Featureless extraction involves directly feeding the network with the characters to be recognized, and the network automatically extracts character features to produce the recognition results.The character recognition algorithm built on neural network has strong self-learning ability, but the network structure is complex, the network model is not suitable for understanding, and the training time is long.

3. Experiments

In the aspect of performance and methods for detecting license plates, character segmentation, and recognition, this study examines the available LPR models. Schemes for recognizing license plates can be roughly split into two categories: multi-level schemes and single-level schemes. The three steps of the multi-stage license plate identification system are character segmentation, character recognition, and license plate detection. Approximately 95% of Automatic License Plate Recognition (ALPR) research conducted over the past two decades has used the multi-stage technique to recognize license plates.

During the license plate detection stage, conventional computer vision techniques are utilized to extract the license plate, taking into account traits such as color, shape, texture, and the presence of characters. Some studies also employ statistical classifiers with Haar-like features to improve manifestation. Object detection using deep learning has also been employed lately, and these methods have shown remarkable performance and robustness under constrained conditions compared to traditional techniques.

About 50% of research using edge-based approaches for license plate recognition are early solutions in the area, which have mostly relied on conventional computer vision techniques. Yet, deep learning techniques that have been used for license plate detection exceed 80% of recent research.

4. Conclusion

With the increasing popularity of smart devices and the fast-paced lifestyle, there is a growing need for efficient and accurate recognition of objects in low-light conditions. License plate recognition technology has been under development for many years, but it still faces significant challenges when it comes to low-light conditions. Despite advancements in deep learning algorithms, license plate recognition under low-light conditions continues to be problematic. This is because low-light conditions make it difficult for cameras to capture clear and well-defined images of license plates, which in turn makes it challenging for algorithms to accurately detect and recognize them. To address this issue, researchers and developers are exploring various approaches, such as improving the quality of cameras and sensors, using advanced image enhancement techniques, and leveraging the latest advancements in deep learning algorithms. These efforts aim to improve the accuracy and speed of license plate detection and recognition under low-light conditions, making it possible to use this technology in everyday situations. However, it is still a challenging research topic, and further advancements are needed to achieve robust and reliable license plate recognition under low-light conditions.

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