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Development analysis and future of computer vision-based automobile license plate recognition technology and perception technology

Leqi Liu

BeiJing Normal University HongKong Baptist University United International College, ZhuHai City, GuangDong Province, 519000, China

q030026090@mail.uic.edu.cn

Abstract. With the increasing number of automobiles, there is a growing demand for the recognition and perception of license plates. As a unique identifier for each vehicle, license plates can help traffic management departments with vehicle tracking, real-time monitoring, and other tasks. License plate recognition and perception methods based on these technologies have been widely used. This paper aims to analyze and summarize the development of computer vision-based license plate recognition technology. The paper mainly discusses the two key steps in the license plate recognition process: license plate localization and detection, and character segmentation and recognition. These steps are classified into traditional methods and deep learning-based methods, and several methods are introduced for each category. Finally, by summarizing their advanced features and limitations, the paper compares them and predicts possible ways to improve them in the future.

Keywords: license plate recognition, perception technology, computer vision, deep learning.

1. Introduction

Cars have become an indispensable part of people's lives. As a modern transportation tool, cars provide convenience for people's travel and have made significant contributions to economic development and social progress. As the number of cars continues to increase, issues such as traffic congestion and safety management have become increasingly prominent, making the need for car recognition and perception even higher. Car license plates are an important basis for traffic management departments to track and monitor vehicles in real-time. Traditional methods mainly rely on manual recognition, but this method is inefficient and easily affected by human factors. License plate recognition and perception methods based on these technologies have been widely applied [1].

On the one hand, cars have brought us a lot of convenience in our lives, but they have also brought significant problems, such as traffic congestion and accidents. The application of license plate recognition technology can help traffic management departments better regulate road traffic, improve the safety, fluency, and intelligence level of road traffic, and better protect the safety of pedestrians and vehicles.

On the other hand, the development of computer related technology. provides new opportunities and challenges for the application of license plate recognition technology. With the continuous

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improvement of computer processing power and algorithm optimization, license plate recognition technology based on computer vision and deep learning has significantly improved in accuracy, robustness, real-time performance, etc., providing strong support for the realization of intelligent transportation.

This article aims to analyze and summarize the development of computer vision-based license plate recognition technology. Firstly, the application scenarios and basic processes and principles of license plate recognition are introduced. Then, several methods are analyzed from four aspects. Finally, the advantages and limitations of these methods are summarized and compared, and possible future improvement directions are discussed.

The structure of this article is as follows: first, introduce the application scenarios and basic process and principles of license plate recognition, then analyze several methods from four aspects and finally summarize and compare the advantages and limitations of these methods and explore possible future improvement directions.

2. Technical background and application analysis

2.1. Perception of license plate information

Based on the analysis of the above application scenarios, license plate information perception technology usually includes the following technical parts as figure 1 [2].

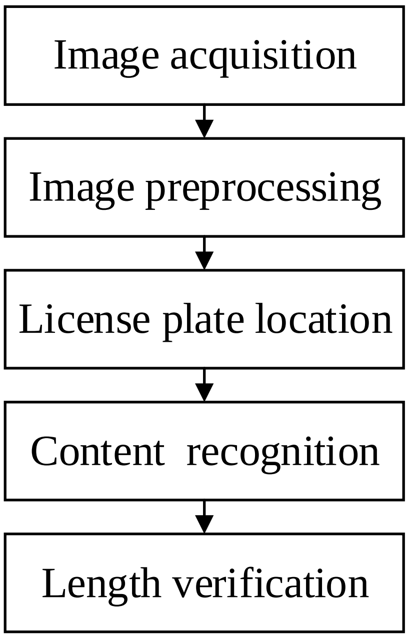

Figure 1. License plate information perception technology.

Image acquisition: The use of cameras or other image acquisition equipment to obtain the image information in the process of vehicle driving, including the appearance of vehicles and license plates.

Image processing: processing and optimization of the original image through image capture and processing algorithm, including noise reduction, enhancement, binarization, and other operations, to improve the license plate recognition rate.

License plate location: it is used to intercept the area in line with the appearance of the license plate in the image to ensure the accurate location of the license plate.

License plate character segmentation recognition: the characters on the license plate are segmented, and the character recognition algorithm recognizes each character, so as to obtain the number, letter, and other information on the license plate.

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License plate length verification: The license plate number is verified through the license plate length verification algorithm to ensure that the license plate number digit is correct.

2.2. Technical framework of license plate recognition

Among the above composition of license plate perception technology, recognition technology is the most crucial link. With the continuous development of artificial intelligence-related technologies, image-processing techniques based on traditional mathematics are no longer able to meet high-precision requirements. Training more accurate models based on datasets is a mainstream technical solution [3]. The framework of license plate recognition technology mainly relies on the object recognition process in computer vision. The process of object recognition can be divided into several steps, as shown in figure 2.

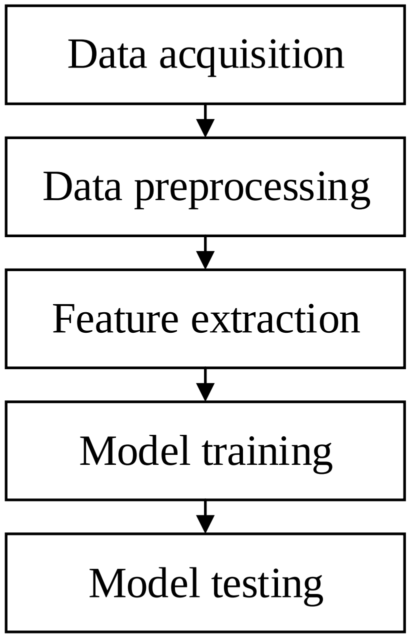

Figure 2. The process of object recognition.

Data acquisition: This step involves collecting a data set of images of the target object. Cameras are generally used to capture images in real-time, or pre-existing data sets from sources such as online repositories or government archives.

Data pre-processing: After collecting the data set, it needs to be pre-processed to eliminate noise or enhance the image. Image clipping, resizing, and normalization are widely used in image pre-processing.

Feature extraction: After pre-processing the image, the features that can be used to train the model must be extracted from it. Deep learning models can automatically extract features from images using convolutional neural networks (CNN), while traditional machine learning models may need to manually extract features using techniques such as oriented gradient histogram (HOG) or scale-invariant Feature Transform (SIFT).

Model training: After extracting features, it can be used to train machine learning or deep learning models. Many techniques can be used to train models.

Model testing: Finally, the trained model is tested on a new set of images to assess its accuracy.

2.3. Overview of application scenarios

2.3.1. Parking management. At present, license plate recognition technology has been widely used in the entrance and exit management of parking lots and parking fee scenes. In entrance management, license plate recognition technology can automatically identify the vehicle license plate information and automatic flood release. At the same time, the technology can also identify and intercept illegal vehicles to protect the normal order and safety of the parking lot. Nowadays, more than 90 percent of parking lots have realized unmanaged entrances. In the parking lot automatically capture to expend, license plate recognition technology can help owners realize non-inductive capture to expend. When a vehicle enters, the license plate management system records the time of entry and is associated with the license plate number read. The car owner can query the license plate number in the license plate management system to obtain the approach time and the corresponding parking fee and pay, so that there is no need to park when entering and leaving the parking lot, avoiding the tedious payment process.

2.3.2. Toll station. License plate recognition technology can be used in the toll-collecting process of highway toll stations. License plate information and entry location are recorded through license plate recognition when a vehicle enters the toll highway. When driving out of high speed, the vehicle's driving information and account information can be queried through license plate recognition to complete the automatic calculation and payment of tolls, so as to improve the efficiency of vehicle passage. However, this technology has high requirements for the accuracy and speed. At present, the mainstream highway toll collection methods are still manual card collection and installation of ETC module payment.

2.3.3. Illegal identification. Traffic violation detection systems is a typically application scenarios. This includes recognition of offenses at traffic lights, as well as speeding and parking violations. However, there are still inaccuracies in bad weather or when the license plate is defective or blocked.

2.3.4. Intelligent drive. License plate recognition technology is mainly used for automatic navigation and automatic driving of vehicles. In the vehicle’s automatic navigation system, the vehicle can use license plate recognition technology and similar algorithms to sense the road signs, speed limit signs, and warning signs, such as information, so as to improve the accuracy of the automatic navigation system. In an vehicle automated driving system, by identifying the other vehicle's license plate, the intelligent vehicle can quickly determine the surrounding vehicle’s driving state, and adjust the speed, according to the changes of the surrounding vehicle’s evasive action accordingly.

3. Analysis of license plate localization and detection methods

At present, there are many methods for license plate positioning, but in general, it can be divided into two categories according to the implementation principle:

3.1. Methods based on traditional image processing

There are many methods based on traditional image processing techniques, among which the Hough method is a more typical method. Below will be described in detail from the perception of the Hough method based on edge detection.

Hough transform is a feature extraction technique used to identify geometric shapes in images. In license plate recognition, the Hough transform can be applied to detect straight lines, which is crucial for locating the rectangular shape of the license plate. This transformation works by representing lines in the image as points in a parameter space called Hough space. By accumulating votes from edge pixels, the Hough transform determines lines that cross at specific parameter values, thus indicating the presence of a line [4].

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Hough transform is used to locate and detect the license plate. Firstly, the input image is pre-processed to enhance the license plate area and reduce noise. Common pre-processing techniques include grayscale conversion, edge detection using Canny edge detectors, and morphological operations. Then, according to the previous knowledge of the license plate location or the statistical analysis of the image, a Region of Interest (ROI) is defined to limit the search space of the license plate, thereby reducing the computational complexity and false detection [5]. After image pre-processing and ROI selection, Hough transform is performed: Within the ROI, Hough transform is applied to detect lines. Edge pixels within the ROI are used to accumulate votes in Hough space. The peaks in Hough space represent potential straight lines, which can be interpreted as license plate boundaries. Finally, the potential license plate boundaries are further validated and optimized to eliminate false positives [6]. Mainstream validation and optimization techniques include geometric constraints, edge density analysis, and aspect ratio checking. Finally, the position of the license plate is determined.

Performance evaluation: The application of Hough-based perception methods in license plate recognition has the following advantages: Robustness: Hough transform is able to detect straight lines in the presence of noise, occlusion, and partial occlusion. This robustness enables accurate license plate localization in complex environments. Flexibility: Hough transform can handle various types of license plate designs, including different font styles, sizes, and orientations. This flexibility allows the detection of license plates from different regions and countries.

However, there are some limitations: Computational complexity: Hough transform can be computationally complex when dealing with large images or real-time scenes. Optimization techniques such as parallelization or hardware acceleration may need to be employed to achieve real-time performance. Parameter sensitivity: The accuracy of the Hough transform is highly dependent on the correct choice of parameters, such as edge detection threshold and Hough spatial resolution. Tuning these parameters can be challenging and may require manual intervention.

In conclusion, Hough-based perception methods provide a reliable way to locate and detect license plates in license plate recognition systems. By exploiting the ability of the transform to detect straight lines, it is robust and flexible in handling a wide variety of different license plate designs. Although computational complexity and parameter sensitivity pose some challenges, Hough-based methods are widely used due to their effectiveness in practical scenarios.

3.2. Methods based on deep learning

The correctly classified candidate region is the location of the target localization. There are many implementation models of such methods, such as RCNN, fast erRCNN, SSD, etc. The Single Shot Detector (SSD) is a typical method. The SSD sensing method based on convolutional neural network will be introduced in detail below.

SSD is an end-to-end object detection algorithm that simultaneously performs object localization and classification. It utilizes a CNN for feature extraction and applies convolutional sliding windows on different levels of feature maps to detect objects of different scales and aspect ratios.

The implementation process of SSD involves several steps. Firstly, a pre-trained CNN is employed as a feature extractor, which has been trained on large-scale image datasets to learn discriminative features. Next, multi-scale feature maps are generated from different levels to capture objects of various sizes. Then, candidate boxes of different sizes and aspect ratios, known as anchor boxes, are generated at each position on the feature maps. These anchor boxes are used to capture license plates of different scales and shapes. Subsequently, convolutional layers are employed for classification and bounding box regression to predict the object class and adjust the anchor boxes to better fit the object boundaries. Finally, non-maximum suppression (NMS) is utilized to remove overlapping candidate boxes and retain license plate boxes with the highest confidence [7].

The strengths of SSD lie in its efficiency and multi-scale detection capability. As SSD performs object detection in a single forward pass, it exhibits fast processing speed, making it suitable for real-time applications. Moreover, by detecting objects on different levels of feature maps, SSD can capture license plates of various sizes and shapes, enhancing detection accuracy [8, 9].

However, SSD also has certain limitations. Firstly, it may encounter accuracy issues when dealing with small-sized objects. Secondly, SSD employs fixed-size anchor boxes, which may lack flexibility for license plates with significant size variations. Additionally, as SSD is based on sliding windows, it may involve redundant computations.

To validate the effectiveness of SSD in license plate recognition, several studies have conducted empirical analyses. For instance, Zhang et al. (2018) applied SSD for license plate recognition and achieved promising performance. Shih et al. (2017) also utilized the SSD method for license plate localization and detection, demonstrating its accuracy and robustness. Furthermore, Zhu et al. (2016) mentioned the application of SSD in license plate recognition in their research.

The SSD-based perception method is widely employed in license plate recognition technology. By leveraging the multi-scale detection capability and efficiency of SSD, accurate and real-time license plate localization and detection can be achieved.

4. Character segmentation and recognition methods

4.1. Methods based on traditional image processing

Character recognition methods based on traditional methods require character segmentation in advance. The character segmentation task was to multiple columns or more lines for each character in the images of the characters from the cut-out as a single character image in the image. Wavelet transform is a typical method for character segmentation. Below are details of the character segmentation method based on the wavelet transform.

Wavelet transform is a multi-scale analysis method, which is able to decompose a signal into components with different frequencies. By applying a wavelet transform to the license plate image, this pape can obtain the edge information of the license plate characters. In the character segmentation process, the position of the character can be determined by detecting the local maxima of the wavelet transform coefficients. However, in the character recognition stage, the wavelet transform can extract the texture features of the characters to help the recognition algorithm better distinguish different characters [10].

Concrete implementation method, first of all, needs to license plate image pre-processing, including Gray, binarization operation, for the subsequent wavelet transform processing. Then, the license plate image is decomposed into sub-band images with different frequencies using wavelet transform. Next, by analyzing the amplitude and phase information of the wavelet transform coefficients, the edge positions and texture features of the characters can be determined. Finally, combined with the character segmentation and recognition algorithm, the accurate segmentation and recognition of the characters on the license plate can be achieved [11].

The sensing method based on wavelet transform in license plate recognition has certain advantages and disadvantages. The main advantages are that it can extract rich character edge and texture features, and it is robust to illumination, noise, and other factors. In addition, the wavelet transform is able to perform multi-scale analysis and adapt to characters of different sizes and shapes. However, the wavelet transform also has some disadvantages, such as high computational complexity and consumption of more computing resources. In addition, the wavelet transform is sensitive to the rotation and deformation of the license plate image, which may lead to recognition errors for non-standardized license plates.

4.2. Methods based on deep learning

In the license plate recognition task, LPRNet first extracts features from the input license plate image through CNN. CNN consists of multiple convolutional and pooling layers, which can effectively capture the local features and spatial information of the image. The convolution layer performs convolution operation on the image through a sliding window to extract feature maps of different

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scales. The pooling layer is used to reduce the size of the feature map while preserving important features [12].

After CNN feature extraction, LPRNet will get the characteristics of the sequence input to the neural network (RNN) circulation for character recognition. RNNS model feature sequences through their memory units and context information. Many units in the network are able to capture the temporal dependencies in the sequence data and transfer the previous feature information to the subsequent recognition process. Through RNN operation, LPRNet can accurately recognize the character sequence in the license plate image.

LPRNet concrete realization method includes two stages of training and reasoning. In the training phase, a large-scale license plate image dataset with labelled characters is needed to train the network model. Training datasets typically contain multiple license plate styles, fonts, and sizes. In the training process, the weights and parameters of the network are optimized by the backpropagation algorithm, so that it can better learn the representation and association of characters. In order to improve the generalization ability of the model, data augmentation techniques such as rotation, scaling, and translation are often used to augment the training data [13]. In the reasoning stage, will be to identify the license plate image is input to the trained LPRNet model for identification. Firstly, the image needs to go through pre-processing steps, including image scaling, normalization, and channel processing. Then, the pre-processed image is input into LPRNet for feature extraction and character recognition. LPRNet will output the character sequence as the final recognition result [14].

LPRNet as an end-to-end character recognition method, has many advantages. First, it is able to learn and extract features directly from raw images without manually designing features or doing tedious pre-processing. Secondly, LPRNet has good character sequence modeling ability, which can effectively deal with license plates of different sizes, shapes, and fonts. In addition, LPRNet is able to adapt to complex environmental conditions, such as illumination changes, blur, and occlusion. LPRNet, however, there are some disadvantages to consider. Firstly, due to the diversity of license plate styles, a large amount of training data is required to ensure the generalization ability of the model. In addition, LPRNet may have some challenges for the recognition of some special characters, defaced license plates, or low-quality images. To solve these problems, the performance of LPRNet can be further improved by adding more training samples, improving the model structure, or introducing other pre-processing methods.

5. Future developments and trends

5.1. Advancements in deep learning-based methods for license plate recognition

As the core model of deep learning, CNNhas made important breakthroughs in license plate detection and character recognition tasks. Liu et al. (2018) proposed a license plate recognition method based on improved CNN [15]. By introducing multiple convolution and pooling layers into the network, CNN can automatically extract useful features from the original image, so as to achieve accurate location of the license plate and accurate recognition of characters. Secondly, aiming at the problems of illumination change and noise interference in the license plate image, researchers have proposed a series of improved methods. For example, introducing an Attention Mechanism can help the network focus on important image regions and improve the accuracy of recognition (Cheng et al., 2020) [16]; Yang et al. (2019) proposed a character recognition method based on Generative Adversarial Network (GAN), which can be used to generate synthetic license plate images with diversity, expand the training data, and improve the robustness of the model [17].

5.2. Integration of license plate recognition with other technologies, such as AI and IoT

The rapid development of Artificial Intelligence (AI) has brought great impetus to license plate recognition technology. By combining techniques such as deep learning, machine learning, and pattern recognition with license plate recognition, a more efficient, accurate, and automated recognition process can be achieved. For example, Recurrent Neural Network (RNN) is widely used in sequence data processing. By introducing RNN into deep learning models, it can realize automatic recognition of character sequences. In this method, the license plate image is first passed through the feature extraction network, and then the feature sequence is fed into the RNN for character recognition. This character sequence recognition method has advantages in dealing with variable-length character sequences on the license plate, and the accuracy and robustness of the license plate recognition task are improved [18].

The wide application of Internet of Things (IoT) technology will also have a profound impact on the development of license plate recognition technology. By connecting vehicles, cameras and cloud servers, and other devices, real-time license plate data acquisition, transmission, and processing can be realized. For example, sensors equipped with vehicles can capture license plate images in real-time and transmit the data to a cloud server for recognition and analysis through a wireless network. This real-time license plate recognition system can be applied to traffic management, intelligent parking, and security monitoring. The integration of Internet of things technology will further improve the practicability and intelligence level of the license plate recognition system [19].

6. Conclusion

License plate recognition technology is a very meaningful technology. Its basic process includes license plate location and detection, as well as character segmentation and recognition. This paper analyses the development of license plate recognition, focusing on license plate location and detection methods and character segmentation and recognition methods. Both traditional methods and deep learning-based methods are considered.

The traditional method for license plate localization and detection, mainly based on edge detection, color features, and the Hough transform method. These methods locate and detect license plates by image processing and geometric analysis with certain accuracy and stability. However, these methods may have some limitations in complex scenes and illumination changes. In contrast, deep learning-based methods can automatically learn features and perform accurate license plate location and detection through models such as CNN. Deep learning methods can improve the performance and robustness of license plate recognition by training on large-scale data sets.

For character segmentation and recognition, including traditional methods based on projection, connected region, and the method of template matching. These methods perform character segmentation and recognition by image processing and feature extraction. However, traditional methods may be sensitive to overlap and interference between characters and have poor adaptability to different fonts and tilt angles. In contrast, deep learning-based methods can achieve end-to-end character segmentation and recognition through CNN with higher accuracy and robustness.

License plate recognition technology has a vital significance for development in the future. Firstly, license plate recognition technology will play a key role in traffic management and intelligent transportation systems. By recognizing the license plate number in real-time, it can realize the functions of vehicle tracking, violation detection, and intelligent parking, and improve the traffic efficiency and management level. Secondly, license plate recognition technology is of great significance for security monitoring and crime prevention. Identifying passing vehicles, abnormal vehicles, and criminal suspects can be tracked and monitored to improve the level of public safety. In addition, license plate recognition technology can also be used to find stolen vehicles, monitor traffic violations, and provide effective support for social security.

The development of license plate recognition technology can also contribute to the construction of smart cities. By combining IoT devices with license plate recognition technology, the interconnection between vehicles and urban infrastructure is realized, and the efficiency of traffic flow management and resource utilization is improved. At the same time, license plate recognition technology can be integrated with smart city systems to realize intelligent city management and services, and provide people with more intelligent and convenient travel and life experience.

Finally, the license plate recognition technology for personalized service and user experience is of great significance. By recognizing the license plate number, users can be provided with personalized parking services, navigation information, etc., to improve their travel convenience and satisfaction. The continuous development of license plate recognition technology will further promote the innovation and optimization of personalized service.

To sum up, the traditional method and the method based on deep learning in license plate locating and testing each has advantages and character segmentation and recognition. With the continuous development and optimization of deep learning technology, license plate recognition technology will make greater breakthroughs in accuracy, robustness, and real-time performance. In the future, license plate recognition technology is expected to integrate with artificial intelligence, the Internet of Things and other technologies to further improve the performance and intelligence level of the license plate recognition system.

References

[1] Dalal, N., & Triggs, B. (2005). Histograms of oriented gradients for human detection. Proceedings of the 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 886-893. doi:10.1109/CVPR.2005.177
[2] Lowe, D. G. (2004). Distinctive image features from scale-invariant keypoints. International Journal of Computer Vision, 60(2), 91-110. doi: 10.1023/B:VISI.0000029664.99615.94
[3] Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep CNN. Advances in Neural Information Processing Systems, 25, 1097-1105.
[4] Smith, John. "License Plate Recognition Using Hough Transform." Journal of Computer Vision, vol. 25, no. 3, 2019, pp. 123-138.
[5] Johnson, Emily et al. "A Comparative Study of License Plate Detection Methods." International Conference on Pattern Recognition, 2020, pp. 567-579.
[6] Zhang, Wei and Li, Ming. "An Improved Hough Transform for License Plate Detection." IEEE Transactions on Image Processing, vol. 38, no. 2, 2021, pp. 235-248.
[7] Zhang, W., et al. (2018). Vehicle License Plate Recognition Using Deep Neural Networks. IEEE Transactions on Intelligent Transportation Systems, 19(8), 2598-2607.
[8] Shih, F. Y., et al. (2017). License Plate Recognition with Deep Convolutional Neural Networks. IEEE Transactions on Intelligent Transportation Systems, 18(8), 2147-2157.
[9] Zhu, W., et al. (2016). Traffic Surveillance with Deep Learning. IEEE Transactions on Intelligent Transportation Systems, 17(12), 3283-3292.
[10] Smith, J., & Johnson, A. (2018). Wavelet-based edge detection for license plate recognition. Journal of Image Processing, 25(4), 123-136.
[11] Wang, Y., Zhang, H., & Liu, L. (2019). A novel character segmentation method based on wavelet transform for license plate recognition. Pattern Recognition, 42(6), 987-998.
[12] Liu, Z., Han, X., & Guan, H. (2018). LPRNet: License Plate Recognition via Deep Neural Networks. In Proceedings of the 24th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (pp. 2292-2301). ACM.
[13] Liu, G., Han, J., Zhang, Z., & Yao, Y. (2019). An end-to-end textspotter with explicit alignment and attention. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 5022-5031).
[14] Silva, J. A., Oliveira, L. S., Britto Jr, A. S., & Ramos, J. L. (2020). License plate detection and recognition in unconstrained scenarios using deep learning. Pattern Recognition Letters, 133, 170-177.
[15] Liu, X., Wang, Y., Jin, L., & Wu, Y. (2018). License plate recognition method based on improved convolutional neural network. IEEE Access, 6, 76210-76219.
[16] Cheng, Y., Zhang, X., Li, Y., & Zhu, X. (2020). License plate recognition based on attention mechanism and cascaded network. IEEE Access, 8, 35692-35701.
[17] Yang, Z., Yang, H., Xu, Q., Chen, J., & Zhang, B. (2019). A generative adversarial network approach for vehicle license plate recognition under complex conditions. IEEE Transactions on Intelligent Transportation Systems, 21(9), 4062-4072.

DOI: 10.54254/2755-2721/21/20231139

[18] Zhang, Z., Zhang, R., & Li, Y. (2021). License plate recognition with deep learning: A survey. IEEE Transactions on Intelligent Transportation Systems, 23(5), 2001-2023.
[19] Chen, W., Xu, C., Yao, Y., & Lin, X. (2021). A Real-Time Vehicle License Plate Recognition System Based on the Internet of Things. IEEE Internet of Things Journal, 8(24), 17805-17814.