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AUTOMATED VEHICLE NUMBER PLATE RECOGNITION IN REAL-TIME USING COMPUTER VISION TECHNOLOGIES

Abstract: The subject of this study is the real-time recognition of vehicle number plates using computer vision technologies. This article explores advanced techniques in object detection and recognition, focusing on the use of YOLOv8 and EasyOCR libraries. YOLOv8 is utilized for accurate license plate detection, while EasyOCR efficiently recognizes text on the plates. The integration of these technologies significantly enhances the accuracy and reliability of license plate recognition systems, making them vital for modern transport management and security applications.

Keywords: computer vision, license plate recognition, transport industry, image processing, AI technologies, YOLOv8, EasyOCR.

The problem statement

In the real world, objects always interact with each other, creating a rich context of associations that can be used by visual systems. Representing the context of an object through its connection with other objects is natural, and statistical aggregation of elements provides additional and effective information for understanding the observed object [1]. Object detection using computer vision is an important part of event analysis, although accurate recognition against the background of similar objects remains a challenge.

Automation of some processes using information technology helps to solve this problem. One of the methods of automation is number recognition using computer vision. In modern conditions, the recognition of vehicle license plates is especially important in public and transport sectors. Thus, there is a need to create a module capable of detecting and recognizing vehicle numbers in real-time, providing important data for computer vision technologies.

Analysis of recent research and publications

Real-time vehicle license plate recognition is one of the current tasks of modern computer vision. This problem attracts researchers' attention due to its wide practical application, particularly in traffic control systems, parking automation, transport security, etc. One of the key aspects in this field is the specificity of visual information processing. The human brain can isolate semantically significant elements of an image, such as contours, shapes, and text, allowing effective symbol recognition even under unfavourable conditions. In contrast, computer systems process data in the space of less significant but easily measurable features, such as colour, texture, pixel intensity, etc. Modern researchers' works highlight methods to overcome these differences. Significant attention is paid to image preprocessing algorithms that ensure brightness normalization, contour extraction, and perspective alignment. Special emphasis is placed on image segmentation methods that allow isolating the license plate from other frame elements, as well as optical character recognition (OCR) algorithms responsible for directly determining the text on the plates.

Among the most common approaches to automated license plate recognition is the use of machine learning methods, particularly convolutional neural networks (CNN). These models demonstrate high accuracy in image classification and text recognition tasks. The application of deep neural networks allows considering complex interconnections between features and adapting to various lighting conditions, plate contamination, and perspective changes.

In addition to the mentioned approaches, the development of automated license plate recognition algorithms is actively researched within the framework of applying different deep learning models. In this context, works dedicated to the implementation of convolutional neural networks (CNN), which allow highlighting key features of license plates with high accuracy, deserve attention. Researchers also emphasize the effectiveness of using multimodal approaches that combine image analysis with contextual information.

The aim and objectives of the research

The aim of this research is to create a module for automated real-time vehicle license plate recognition using computer vision technologies to ensure high accuracy and system performance under various external factors. The main research tasks include analysing modern computer vision technologies and text recognition methods, developing a model for image preprocessing, integrating machine learning methods for symbol recognition, optimizing system performance in real-time, and testing and evaluating the accuracy of the developed module.

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Module development

The development of a module for automated number plate recognition (ANPR) involves creating a reliable software solution capable of operating in real-time with high accuracy. The main stages of development included selecting the model architecture, preparing the environment, implementing image processing algorithms, and optimizing for performance.

For the implementation of the main recognition algorithm, the YOLOv8 model was chosen, which demonstrated high speed and accuracy during testing. Various YOLOv8 variants (nano, small, medium, large, x-large) were compared based on mAP50, mAP50-95 metrics, and inference speed, allowing the determination of the most optimal variant for real-time use.

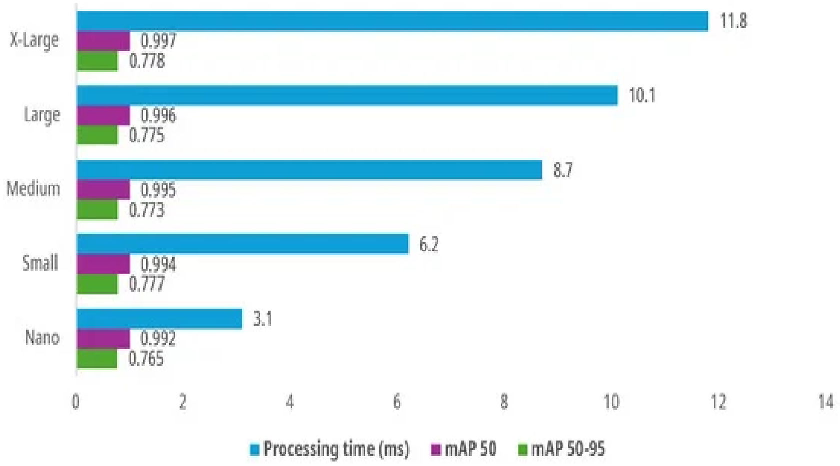

Figure 1. Comparison of the performance of YOLOv8 variants for license plate detection

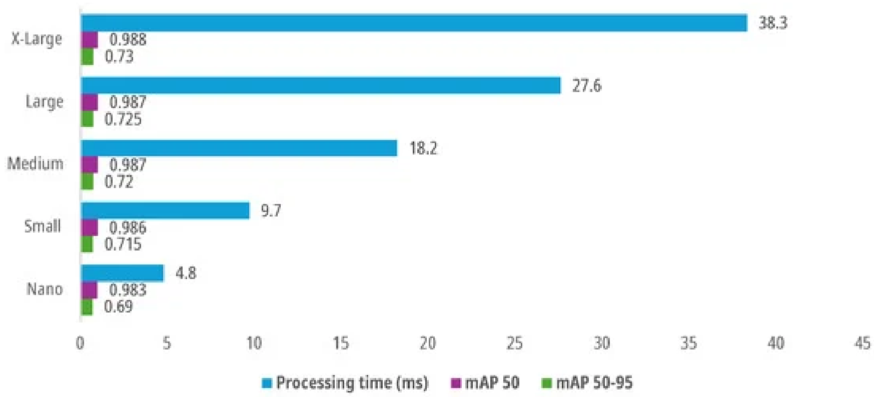

Figure 2. Comparison of the performance of YOLOv8 variants for digit recognition

The model training was conducted in the Google Colab environment, which provided access to powerful GPU resources. All necessary libraries, including PyTorch and the YOLOv8 library for integrating computer vision algorithms, were installed. The training process used a dataset annotated on the Roboflow platform, which was imported into the environment using Python 3.10.

Before training, the model underwent an image preprocessing stage. All images were normalized and adapted to a standard size to match the input layer of the neural network. Data augmentation techniques such as rotation, brightness, and contrast adjustment were used to increase the variability of the training set.

The model training process included optimizing hyperparameters such as learning rate, batch size, and the number of epochs. Parameters were carefully selected through experiments to achieve the best results. Training was accompanied by monitoring key performance metrics, including classification loss and mean average precision (mAP).

To enhance inference speed, the module was optimized by reducing the model size and using hardware acceleration. This allowed achieving a balance between performance and accuracy in real-time conditions. As a result, the developed module demonstrates the ability to effectively recognize vehicle license plates even under challenging conditions, such as low lighting or different viewing angles.

The final phase of the project involves integrating the trained ANPR model into a functional system and deploying it in real-world conditions. A Python script was developed that covers the entire ANPR process from inputting an image or video to extracting the license plate. The script includes several key functions:

- Car Function: Uses the YOLOv8 model trained on a dataset to detect vehicles in the input image or video;
- Plate Function: Uses a specially trained YOLOv8 model to locate and isolate the license plate in the detected vehicle area;
- Number Function: Uses another specialized YOLOv8 model to recognize and interpret individual digits on the isolated license plate;
- ANPR Function: The main function that coordinates the entire process, sequentially calling the above functions and handling any exceptions or fallback scenarios.

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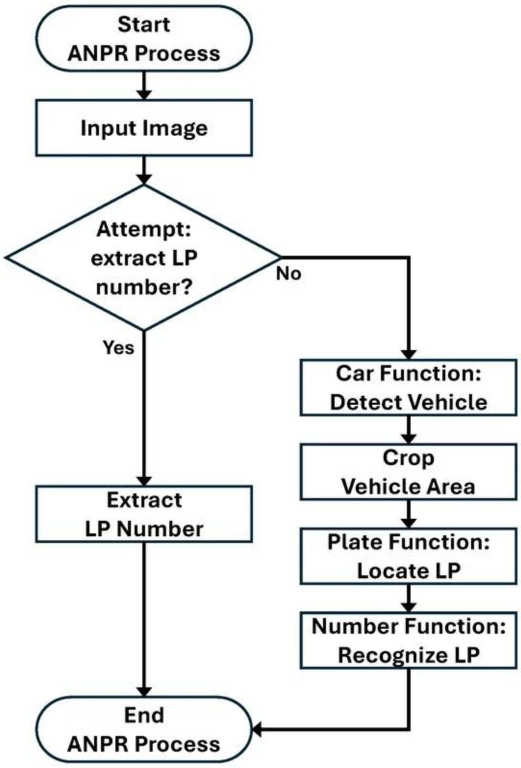

Figure 3. Block diagram of the image preprocessing algorithm

To ensure efficient real-time processing, a local solution was implemented. The Python script accepts images or videos, processes them using the ANPR script, and returns the extracted license plates. Using a local solution avoids dependency on external servers, which increases the system's reliability and speed. This approach also ensures scalability and adaptability to various operating conditions.

Research results

Computer vision is a field of computer science that focuses on enabling computers to identify and recognize objects and people in images and videos. Like other types of AI, computer vision aims to perform and automate tasks that replicate human capabilities. In this case, computer vision attempts to replicate both how a human sees and how a human interprets what they see [2].

Computer vision systems are used for object classification by analysing visual content and determining the categories of objects in photos or videos. For example, they can recognize a dog among other objects in an image. Identification technologies help to determine a specific object in a photo or video. For instance, the system can find a specific dog among many in an image.

Object tracking allows systems to process video materials, find objects that meet specified criteria, and track their movement. Computer vision technology aims to mimic the work of the human brain, using patterns to decode objects. These principles are applied to create computer vision systems that include various methods of image recognition and processing. Object recognition is a computer vision method for identifying, locating, and classifying objects in digital images or real-world conditions. The goal of this technique is to enable computers to analyse images and detect certain patterns or shapes.

Computer vision also finds applications in the military field. Artificial vision systems speed up and facilitate tasks that previously required significant human resources. Computer vision is an important technology for the development of autonomous vehicles, which are significant in the defence sector, providing access to dangerous places with fewer restrictions. The technology is also used to control autonomous weapons, such as combat drones and killer robots. This weapon can autonomously perform lethal actions without human intervention and provides greater accuracy in recognizing terrain and target objects, combining GPS data with field data to refine targets and avoid collateral damage.

The license plate recognition subsystem uses computer vision technology to automatically recognize and identify license plates on vehicles. This system analyses images or video footage from surveillance cameras, isolates the license plates, and recognizes their characters, allowing for the automation of vehicle identification and tracking processes [3].

One of the main functions of this subsystem is the detection of the license plate in an image or video. The technology allows determining the position of the plate among other objects in the image. After that, the process of recognizing the characters on the plate is performed, which allows obtaining the exact text of the license plate.

License plate recognition subsystems are widely used in various fields. For example, in the transportation system, they are used for automatic traffic rule enforcement, toll road entry, and vehicle tracking. They are also used to automate processes in parking lots, ensuring quick and accurate tracking of vehicle entry and exit [4].

These systems significantly reduce the need for human intervention, increasing the efficiency and accuracy of tasks. Computer vision algorithms in these subsystems can process large volumes of data in real-time, ensuring quick and accurate license plate recognition even in challenging conditions, such as poor lighting or high traffic flow.

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Computer vision technologies for license plate recognition use various methods, including machine learning and neural networks, which allow them to adapt to different conditions and improve recognition accuracy. These systems can be integrated with other information systems, such as vehicle databases or payment systems, providing a comprehensive approach to managing transportation infrastructure.

License plate recognition also contributes to security by allowing the tracking of suspicious vehicles, controlling access to certain areas, and identifying violators. Algorithms can combine data with GPS to improve identification accuracy and optimize routes. [5]. The use of computer vision in this field is a significant step towards the development of intelligent transportation systems and enhancing the safety and efficiency of traffic management.

To design the system and describe the model, the YOLOv8 architecture is presented, which is a new version in the series of real-time object detectors YOLO. YOLOv8 offers advanced features in terms of accuracy and speed, making it ideal for various object recognition tasks [6]:

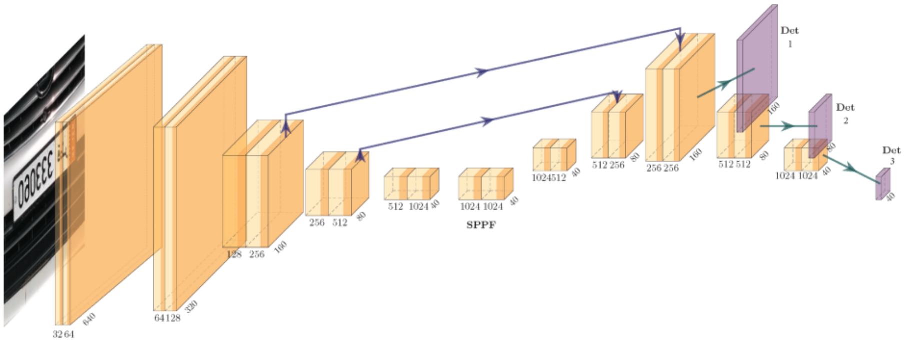

Figure 4. YOLOv8 architecture

Figure 5. Results of license plate recognition using
the proposed method based on the trained YOLOv8 model

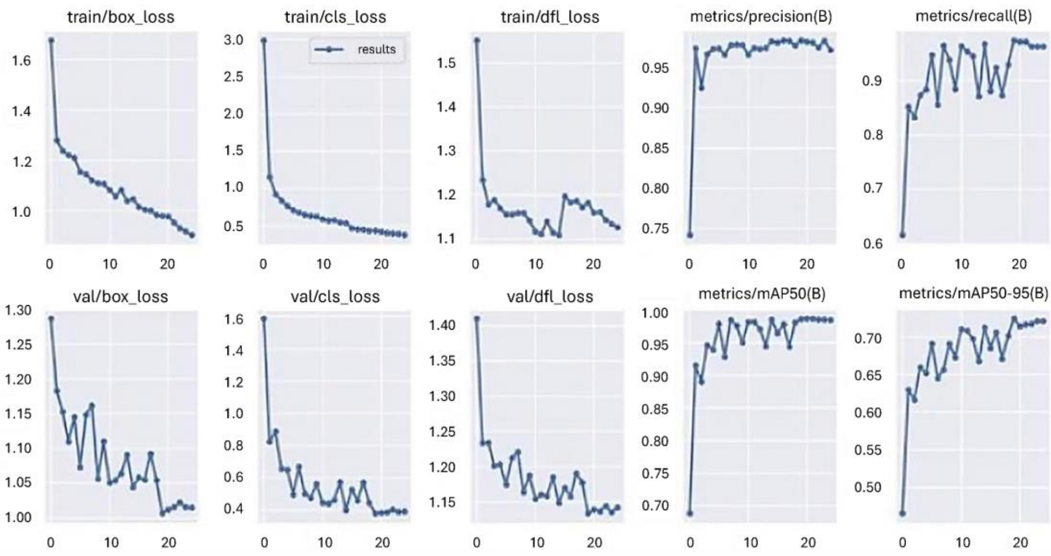

Figure 6. Dynamics of training and validation losses
and model performance metrics over epochs of training

Fluctuations in the loss function observed on the graph can be attributed to several factors. Firstly, the diversity of the dataset, which includes complex environmental conditions, contributes to these fluctuations during training. The model adapts to different types of challenging examples, leading to temporary increases in loss. Additionally, the use of data augmentation methods introduces additional variability into the training samples, which can cause short-term fluctuations as the model adjusts to these changes. Finally, the learning rate schedule and batch size selection can also impact these fluctuations. Despite this, the overall trend of decreasing loss and improving accuracy and recall metrics indicates effective model training and its ability to generalize data.

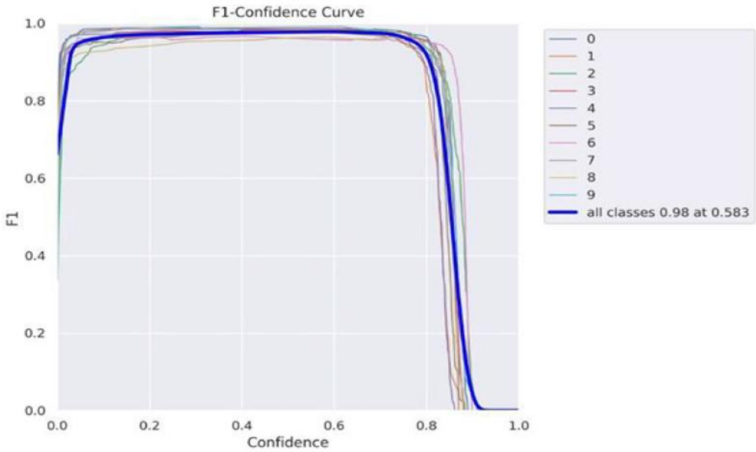

Figure 7. F1 curve for the YOLOv8 model

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The F1 curve in figure 7 demonstrates the model's ability to effectively balance precision and recall. High F1 scores across different confidence intervals indicate high efficiency in license plate recognition.

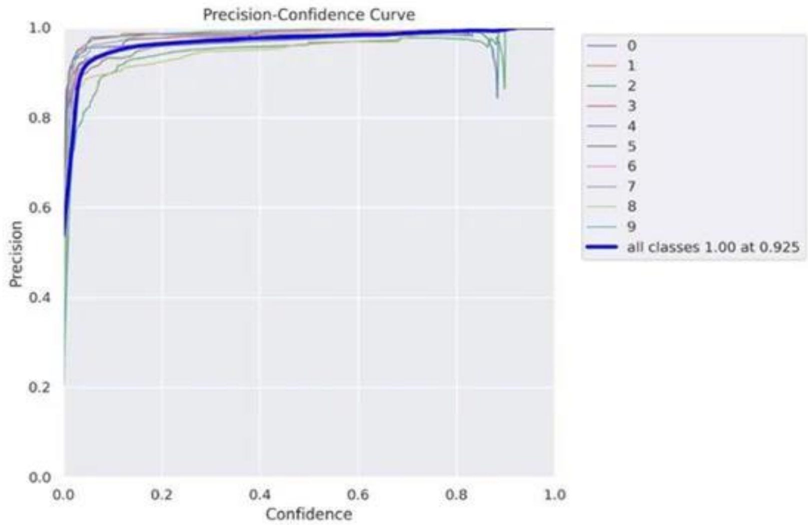

Figure 8. Precision curve for the YOLOv8 model

Figure 8 shows the model's accuracy at different confidence intervals. High accuracy values, especially at high confidence levels, indicate that when the model makes a positive detection, it is highly likely to be correct.

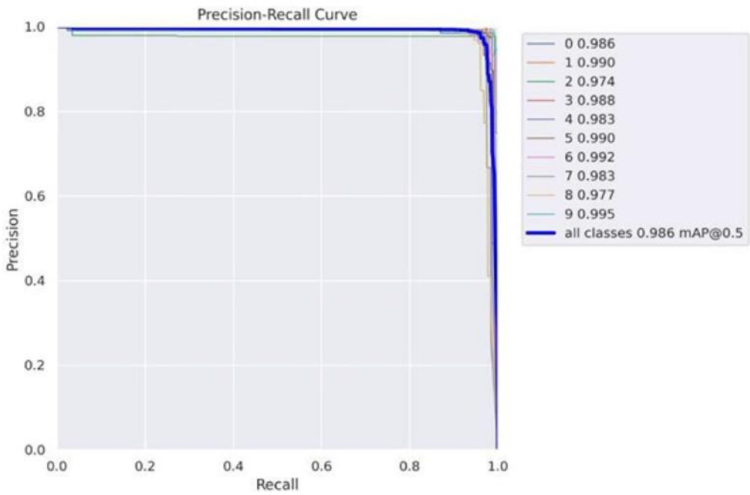

Figure 9. Precision-recall curve for the YOLOv8 model

The precision-recall curve in figure 9 illustrates the trade-off between precision and recall at different threshold settings. A large area under this curve clearly indicates excellent model performance, demonstrating its ability to maintain high precision even as recall increases.

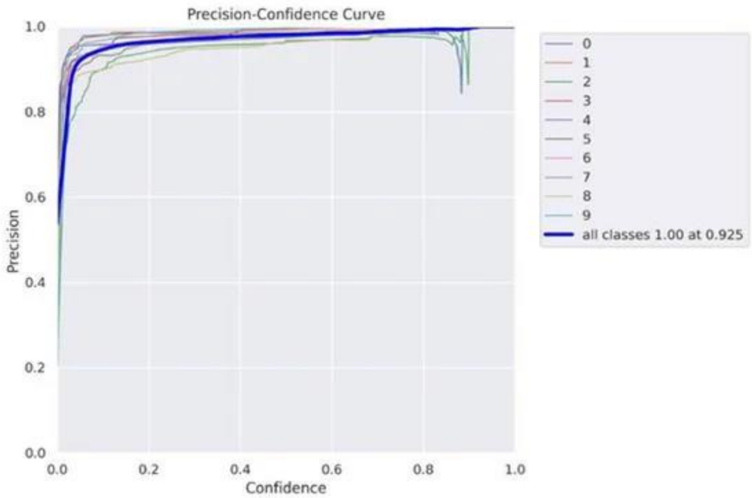

Figure 10. Recall curve for the YOLOv8 model

Figure 10 demonstrates the model's performance across different confidence intervals. High recognition rates indicate that the model effectively identifies a large proportion of actual license plates in images.

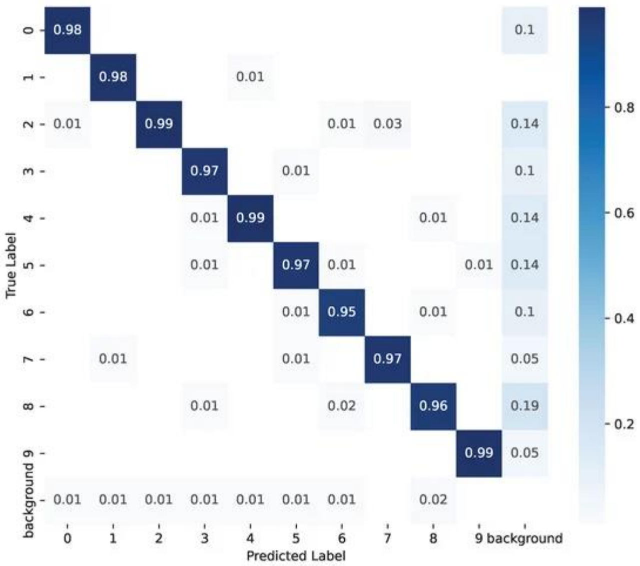

Figure 11. Confusion matrix for the YOLOv8 model

The confusion matrix in figure 11 showcases the model's accuracy in classifying individual license plates. A pronounced diagonal structure with high values signifies excellent classification efficiency across all number classes. Notably, the lack of substantial off-diagonal elements indicates minimal misclassification between different digits, highlighting the model's proficiency in distinguishing visually similar digits (e.g., 8 and 0, 1 and 7, 2 and 5).

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Conclusions and future research prospects

This work successfully developed and implemented an advanced automatic number plate recognition (ANPR) system, specifically adapted for various license plates and challenging environmental conditions. The research made a significant contribution to the development of ANPR, demonstrating the effectiveness of the YOLOv8 model, particularly the YOLOv8s variant, in achieving high accuracy and computational efficiency for both license plate detection and recognition tasks. The model's results, with an mAP50 value of over 0.98 for license plate detection and 0.986 for number recognition, set a new standard in ANPR systems.

The vehicle license plate recognition subsystem based on the YOLOv8 architecture shows significant potential for application in various fields, such as transportation, security, and automation. The research results indicate high recognition accuracy and speed, making this technology effective and reliable in real-time conditions.

The application of YOLOv8 for license plate recognition achieves high accuracy and speed due to the improved backbone and neck architecture, as well as the use of the anchor-free split Ultralytics Head. Experiments confirmed the algorithm's effectiveness even in challenging conditions, such as poor lighting, various weather conditions, and high traffic flow. It was found that the diversity of the dataset and the use of data augmentation methods contribute to the overall performance of the system.

One of the main advantages of using YOLOv8 is its ability to process large volumes of data in real-time, which is critical for applications in transportation systems and security. However, there are certain challenges related to adapting the system to new types of license plates, which may vary depending on the country or region. Another important issue is the need to improve algorithms to reduce false positives and negatives in challenging operating conditions.

Future research will focus on improving the model architecture to enhance its robustness to various operating conditions. In particular, the development of new data augmentation methods and the application of advanced machine learning techniques can further improve recognition accuracy. Additionally, integrating the license plate recognition subsystem with other information systems, such as vehicle databases, payment systems, and traffic management systems, can provide a comprehensive approach to managing transportation infrastructure. Another promising direction is exploring the potential of using the license plate recognition subsystem in the context of smart cities and intelligent transportation systems (ITS). This includes integration with traffic control systems, automatic payment systems, as well as security and monitoring systems. Ensuring data privacy and compliance with legal regulations governing the use of surveillance technologies is also an important aspect.

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