Multi-vehicle License Plate Recognition based on YOLOv9

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Abstract

Existing license plate recognition models cannot locate license plates in the case of complex backgrounds and multiple vehicles. Due to the lack of a dataset with license plates under different situations, most existing multiple license plate detection models must have two recognition steps, namely vehicle detection and license plate detection, which could be more efficient. In this paper, we made a new dataset to overcome the problems of insufficient data on the multi-vehicle environment among existing public datasets. YOLOv9 object detection model is used to verify the validity of the collected dataset. The experimental results show that the average recognition accuracy of Yolo is 81.3% with the new multi-vehicle dataset and 99.5% in the existing single-vehicle dataset, which shows that the collected dataset is more complex than the existing one.

Ⅰ. Introduction

License plate recognition plays an important role in the intelligent transportation system, as it tracks stolen vehicles, monitors traffic, enforces speed limits, and allows automatic parking. The important task is localizing the license plate in image frames.

Compared to traditional methods, such as morphological features [1], deep learning-based solutions are not compromised by the poor quality of images and also outperform them. Existing license plate datasets lack environmental information [2]. Therefore, most works first detect the vehicle and then identify the license plate within the vehicle's bounding box [3]. The current research mainly uses datasets in parking lots, speed cameras, and other non-complex scenarios where the backgrounds are fixed. It is difficult for the model to cope with the dynamic background during practical driving environments.

This study collects a new dataset from practical driving environments, including cities, highways, and mountains. Based on the new dataset, the trained YOLOv9 [4] model avoids the detection of vehicles but directly detects the license plate due to complexity. It benefits in two ways: First, it can detect license plates of surrounding vehicles using the car's internal cameras. Second, it uses multi-vehicle datasets, which reduces computational complexity.

Ⅱ. Model

In the task of license plate recognition, the camera frame contains various image blocks with different objects, which may include the license plate. For the subsequent process, it is necessary to separate the targets of the license plate from the background. This paper uses YOLOv9 to handle this task.

YOLOv9 is an object detection system proposed by Wang *et al.* in 2024. YOLO is a one-stage algorithm that combines object location and classification tasks. It considers object detection as a regression problem that detects the whole image and outputs the bounding box at once.

YOLOv9 consists of four parts: input, backbone, neck, and prediction. The input converts the image size to 640×640×3 and processes the image by the data enhancement method. Backbone is a main feature extractor to get meaningful features from the input. YOLOv9 backbone mainly uses Conv and RepNCSP-ELAN4 blocks. RepNCSP-ELAN4 is a new block that contains RepNBottleneck [5] and a generalized efficient layer aggregation network (GELAN). GELAN is a new attention neural network that fuses ELAN and any computational blocks in CSPNet.The neck uses different-level PAN modules to enhance the feature representation and aggregation. The prediction freely chooses the suitable intersection over union (IoU) loss function and outputs the bounding boxes. In YOLOv9, a new framework called programmable gradient information (PGI) has been introduced to capture lost features in the shallow layers, which overcomes the information bottlenecks. YOLOv9 has become a more efficient and lightweight mainstream model due to GELAN and PGI.

III. Dataset

The dataset used for this study includes the open-source Chinese city parking dataset (CCPD) [6] and the multi-vehicle license plate datasets. Fig. 1 shows samples from two datasets. The CCPD dataset has huge images of Chinese domestic license plates in the parking lot used for license plate recognition. The dataset contains photos of license plates in various environments, such as blurred, tilted, cloudy, rainy, and snowy days. However, CCPD needs more environmental backgrounds, such as roads, walls, and traffic signs, mainly covering the same province. Another drawback is that most of the license plates have a blue background.

(a) (b)

Fig. 1. The dataset samples: (a) CCPD's image only for a single vehicle parked. (b) Developed multi-vehicle image.

CCPD only includes an image of a vehicle parked. The dataset contains photos of license plates in various environments, such as blurred, tilted, cloudy, rainy, and snowy days. However, CCPD lacks environmental backgrounds, such as roads, walls, and traffic signs, and it mainly covers the same province. Another drawback is that most of the license plates have a blue background.

The multi-vehicle dataset is a diverse license plate dataset captured in various road conditions. These videos were collected from the vehicle's front camera. Images contain cars in front of the camera, oncoming cars, and parking cars. Labels are manually done for multi-vehicle datasets.

IV. Experiments

The experiments are conducted based on 120,000 training images and 40,000 validation images from CCPD. The multi-vehicle dataset uses 1,000 images for training and 200 images for testing.

YOLOv9 is trained by 100 epochs for each dataset. The batch size is 16, and the learning rate is 0.01. YOLO model was initialized with the YOLOv9 official model's weights before training using CCPD dataset. Since the new multi-vehicle dataset is small, the model is further pretrained using the results from CCPD training.

The evaluation metrics are precision, recall, and mean average precision (mAP). Precision means how many of the positive predictions are really correct, and recall shows how many of the true positive cases are in the class.

TABLE I.
COMPARING THE EVALUATION METRICS BETWEEN TWO DATASETS USING THE YOLOV9 MODEL.

Dataset	Precision	Recall	mAP50
CCPD	0.999	0.999	0.995
Multi-Vehicle	0.905	0.732	0.813

The results show that the multi-vehicle dataset has advantages in diverse environments despite the small sample size because mAP50 is reduced by almost 20%.

An individual example of a test image in a multi-vehicle dataset is shown in Fig. 2. It can recognize various vehicle license plates in real-time.

Fig. 2. Real-time test of YOLOv9 trained by multi-vehicle dataset.

V. Conclusion

In this paper, a new dataset collected in real traffic was constructed for multiple license plate detection. It is more general and practical compared to the existing single license plate datasets. This study uses the YOLOv9 model to detect and perform license plates in real-time. With this experience, we can perform more dataset collection and model improvements in the future.

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