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# Research on Curve Lane Detection Method Based on Deep Learning

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Abstract. Curve Lane detection is an indispensable part of auto-sensing technology, and plays a key role in auto-driving. The traditional curve lane detection methods are based on Hough transform and YOLOv5 Algorithm. Based on Hough transform method, the detection effect is not ideal when the lane line is discontinuous and short, that is, the dotted line is prone to detection errors. Yolov5 Algorithm is not effective for continuous lane detection or long lane detection. In this paper, deep learning based on the combination of Hough transform and Yolov5 Algorithm is studied, which can effectively detect the solid line and dotted line, and can accurately detect the curve. The experimental results show that the curvature radius, which is of great significance for reducing the probability of traffic accidents on the curve section.

Keywords. Deep learning; Hough transform; YOLOv5 algorithm; Curve lane detection

#### 1. Introduction

The rapid development of 5G technology and the further development of China's Beidou navigation and its in-depth application in many fields have provided a very broad stage for the development of autonomous driving technology in daily life applications. However, the safety performance of autonomous driving still needs to be improved, Completely safe automatic driving has not yet been achieved, leading to frequent accidents in autonomous driving test-drive experiments, and ultimately failed to be widely applied, research in the field of autonomous driving is still facing challenges.

The curve section is the peak section of traffic accidents. The curve lane detection is also the key part of the auto-driving perception technology, which regulates the range of the vehicle driving route on the curve and plays a vital role in the safe operation of autonomous driving [1]. Traditional lane detection methods are mostly based on image processing technology. Hough transform is usually used to extract lane features, and the detection results are ideal for long lane, i. e., solid lane [2, 3]. With the development of deep learning technology, we can solve the problem of lane detection in the curve from the angle of deep learning, especially, the YOLOv5 algorithm is used as the basic algorithm, which has a good effect on the detection of the curve and the shorter lane, but the detection effect of the continuous lane or the longer lane is limited by the annotation

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method of the training data set, the detection effect is still not ideal [4,5]. Therefore, combining Hough transform with YOLOv5 algorithm, the method can detect solid and dotted lane effectively, and can detect the curve accurately.

#### 2. Principle of Curve Lane Detection Method

## 2.1. A Approach for Curve Lane Detection Based on Hough Transform

Hough transform is a method of parameter estimation using voting method. The basic idea is to combine Hoff parameter space with image space on the basis of on-line-point duality, the detection problem in image space is transformed into parameter space[6]. In simple terms, Hough transform is a method to find straight lines, circles and other simple shapes in an image.

The basic principle of Hough transform is to find the solution of the maximum value by cumulating the points in space, and then find the graph that needs to be detected. Suppose that there is a straight-line L whose perpendicular distance from the origin to the x-axis is  $\rho$ , and the angle between the perpendicular line and the x-axis is  $\theta$ . Then this line is unique, and the Formula 1 is as follows:

$$\rho = x \cos\theta_+ v \sin\theta \tag{1}$$

The schematic diagram of the Hough transform for a line is shown in figure 1:



Figure 1. Schematic diagram of line Hough transform

What you can see in figure 1 is that this line corresponds to only one  $(\rho, \theta)$  in polar coordinates. Changing the size of one of the parameters will change the line in space, thus, the curve of any known expression can be detected.

Hough transform is effective for detecting Continuous lines and inverted lines with incomplete or unclear shapes, but it is not effective for discontinuous lines, the detection effect of the lane line with short length, namely dotted line and it is easy to have the situation of false detection and missed detection.

#### 2.2. A Curve Lane Detection Method Based on Yolov5 Algorithm

YOLOv5 was officially released on June 10, 2020. YOLOv5 is not a single model, but a family of models including YOLOv5s, Yolov5m, YOLOv5l, and YOLOv5x[7]. The YOLOv5m model was chosen for training and testing.

YOLOv5 is a one-stage target detection algorithm, which is improved by adding some new ideas on the basis of YOLOv4, these include: Mosaic Data Enhancement, adaptive anchor frame calculation, adaptive image scaling operation at the input; Focus and CSP structures at the reference end; SPP and FPN + Pan Structures at the Neck end; loss function GIOU at the Output End; and DIOU selected by the prediction box.

When detecting the curve lane based on YOLOv5 Algorithm, it has good effect on detecting the lane-line in the curve and the shorter lane, however, the detection effect of continuous lane or long lane cannot be well detected because of the limitation of the annotation method of the training data set.

# 3. Process of Hough Transformation Combined with Yolov5 Algorithm Based on Deep Learning

Based on the excellent detection effect of Hough transform in continuous long lane and the good detection effect of YOLOv5 Algorithm in curve and short lane, the YOLOv5 Algorithm is used as the main body, combined with Hough transform method and YOLOv5 Algorithm, the general idea of curve lane detection is: Firstly, the input image is preprocessed, and then the curve lane detection based on Hough transform is performed, then, YOLOv5 Algorithm is used to detect the curve lane after Hough transform detection, and finally achieve the detection results for all types of lane and curve lane.

In the course of lane detection based on the Hough Transform, a PyCharm-based development environment was configured to install the OPENCV3.4.1 computer vision library in PyCharm[8,9]. First, lane lines are extracted by edge extraction and color threshold, then perspective transformation is used to transform the image into perspective, histogram statistics is used to determine the location of left and right lanes, and Hough transform is used to fit the lane, finally, the detection result is replaced on the image by perspective transformation.

In curve lane detection based on YOLOv5 Algorithm, the YOLOv5 algorithm folder downloaded from the official website for training and testing, the detection flow chart as shown in figure 2, including the following flow, the final detection results.

1. Filter lane line images with curves, adjust the size of the images uniformly, and preprocess the images as input for the training of the whole network.

2. Send the preprocessed images into the network to extract the features of the laneline with curves.

3. The extracted features are sent to the YOLOv5 Algorithm Network for feature stitching.

4. The stitched features are sent to the YOLO layer for training, and after reaching the number of training iterations are stopped to complete the training and generate the weight model.

5. In the same network, using the trained weight model, the curve lane detection is performed on the pictures in the test set.



### 4. Experimental Verification and Comparative Analysis

The experimental results show that the proposed method is effective in the detection of Curve Lane, which is based on Hough transform and YOLOv5 Algorithm.

# 4.1. Model Training

The model-training software is based on version 6.0 of YOLOv5 and operates on Windows 10, and uses Tuson's Tusimple dataset, known as TUSIMPLE2017. The TUSIMPLE2017 dataset contained 5,000 clear images, 1200 images with clear road

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conditions were selected as the training set for this experiment, and 300 images with curves were selected as the test set.

Before the model training, the relevant program files under the Root Directory of YOLOv5-curve in the software were modified to solve the problem of lane curve recognition.

1. Modify the Yaml file on the dataset. The path, train, val and test in the application file are the paths of the dataset, with the number of categories nc set to 2, the names of categories are defined as curve and line.

2. Modify the Yaml file for network parameters, that is, to modify the YOLOv5m.yaml file to change the corresponding part of the program file to YOLOv5m.

3. Changes to train.py parameters, including weights, cfg, data, epochs, batch-size, img-size, project.

After all the relevant program files have been configured, the train.py file is executed to start training. During the training, the tensorboard tool can be use to view the specific data and effects of each round of training in the generated web page according to the PyCharm terminal section, and form the training log as shown in figure 3.



Figure 3. Training log

As can be seen from figure 3, with the number of training rounds increased, the accuracy gradually improved in the first 30 rounds of training, and changed slightly during the 30 to 150 rounds, and finally maintained at about 0.82. With the number of training rounds increased, the recall increased gradually in the first 30 rounds of training, and changed slightly in the 30 to 150 rounds of training, and finally maintained at about 0.83. The whole situation of training log accords with the law, and the training result is good.

#### 4.2. Comparative Analysis of Test Results

Combining the Hough transform method and YOLOv5 Algorithm, the lane-line detection is performed by using YOLOv5 algorithm after Hough transform detection, and the detection results are shown in figure 4.



a) Lane inspection chart of right-turn lane with

larger curvature radius

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b) The curve lane detection chart with small curvature radius

Figure 4. The curve lane detection result graph combined with Hough transform and YOLOv5 algorithm

Through the a) of figure 4, it can be seen that the detection method based on the combination of Hough transform and YOLOv5 is more accurate in detecting the curve part of right-turn lane with larger curvature radius, the part of solid lane, the part of short lane, the part of dotted lane, and so on. The confidence level can reach about 90%, which overcomes the problem that the detection method based on YOLOv5 algorithm is not good in detecting the long lane, the part of solid lane.

From the b) of figure 4, we can see that the method based on the combination of Hough transform and YOLOv5 can also detect the dotted line in the curve with small curvature radius, and the confidence level can reach 86%, which overcomes the problem of inaccurate detection of the dotted line in the curve lane detection based on Hough transform.

Therefore, the detection method based on the fusion of Hough transform and YOLOv5 Algorithm has a good detection effect for the complicated road condition and the curve lane.

### 5. Conclusion

Based on the limitations of Hough transform and YOLOv5 Algorithm in the detection of lane-line in the curve, this paper proposes a YOLOv5 algorithm based on Hough transform and YOLOv5 algorithm, YOLOv5 algorithm is used to detect the curve lane after Hough transform detection, and realizes the detection of all kinds of lane and curve lane. The experimental results show that the proposed method, which combines Hough transform with YOLOv5 algorithm, can detect both solid and dashed lane, and can detect the curve accurately.

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