ISBN: 978-981-94-1156-6
2024 the 14th International Workshop on Computer Science and Engineering (WCSE 2024)
doi: 10.18178/wcse.2024.06.006

Research on Vehicle Tracking and Collision Detection Method

Hong Weitian, Qi Tengfei, Liu Wenhao and Li Shaowei +

School of Artificial Intelligence, Jianghan University, China

Abstract. In order to quickly identify road vehicle collision accidents, a vehicle collision detection method based on machine vision is proposed. This method first uses the YOLO V5 deep neural model to achieve rapid recognition of vehicles; On this basis, Kalman filtering and Hungarian matching algorithm are introduced to achieve multi target tracking of vehicles; Finally, using the visual odometry calculation method, parameters such as vehicle speed, overlap, and trajectory deflection are obtained, and the occurrence of a collision is judged by whether the above parameters are abnormal. The test results show that compared with existing algorithms, this method has a significant improvement in recognition accuracy.

Keywords: collision detection, computer vision, multi-target tracing, visual odometry

1. Introduction

Applying machine vision methods to road vehicle collision detection can effectively improve the rescue rate of traffic accidents and reduce property losses [1-5]. Chen Ruidong et al. proposed a vehicle recognition, tracking, and collision detection method based on Kalman filtering in their paper [6]; Ao Bangqian et al. proposed a research on motion vehicle detection and tracking method based on improved frame difference method and Camshift algorithm [7]; Lin Fei et al. proposed a traffic accident detection method based on the hybrid hierarchical bounding box algorithm [8].

This paper applies the lighting enhancement model to the preprocessing of the original image and uses the YOLO V5 model to complete vehicle recognition; Simultaneously using Kalman filtering and Hungarian matching algorithm to achieve multi-target tracking; Finally, the visual mileage calculation method is used to calculate the vehicle speed and combine the target overlap and trajectory deviation to achieve collision detection.

2. Image Preprocessing and Target Recognition

2.1. Light Enhancement Preprocessing

Applying lighting enhancement algorithms to image processing can help improve image visibility and detection accuracy. Based on the dark light image enhancement model proposed by Wang Leiyu et al. [9], the image is decomposed into structural and detail layers, and these two layers are processed separately to achieve the enhancement effect.

Fig. 1: Comparison of Lighting Enhancement Preprocessing Effects

The Figure 1 shows a comparison of the effects obtained after light enhancement preprocessing, where the left image is the original image and the right image is the image after light enhancement preprocessing.

+ Corresponding author. Tel.: 86-18171385977.
E-mail address: 55440881@qq.com.

2.2. Target Recognition

Compared to traditional methods such as Viola Jones and DPM, the deep neural network model using YOLO V5 has higher detection accuracy and faster inference speed in target recognition. As shown in Figure 2, the target (vehicle) recognition effect is shown under the condition of 1920 × 1080 resolution and 30fps.

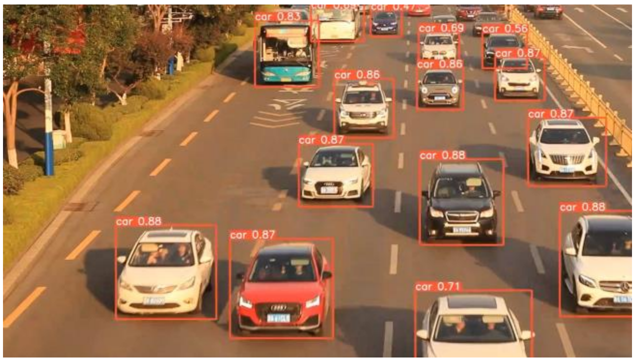

Fig. 2: Target Recognition

3. Multi Target Tracking Algorithm

The combination of Kalman filtering and Hungarian matching algorithm can effectively achieve multi-target tracking [10-12].

Kalman filtering is a recursive state estimation algorithm used to estimate the state variables of a system.Through iterative updates, Kalman filtering can achieve accurate tracking of target states in the presence of noise and uncertainty; The core idea of the Hungarian matching algorithm is to construct a bipartite graph, taking the target and tracking results as the two vertex sets of the graph, and determine the best match by finding the maximum weight match.

The implementation process of multi-target tracking is shown in Figure 3:

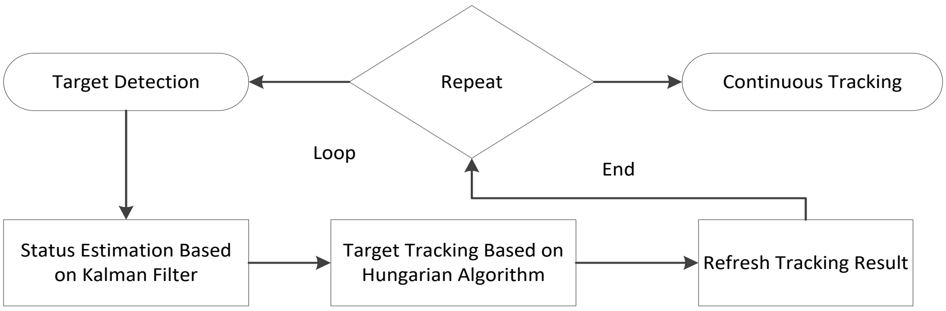

Fig. 3: Multi target tracking implementation process

By combining Kalman filtering and Hungarian matching, multi-target tracking algorithms can achieve accurate tracking of targets in complex environments.

4. Collision Detection

4.1. Speed Calculation

Visual odometry was proposed by Matthies et al. [13] in 1980. The visual mileage calculation method based on monocular cameras consists of the following four parts:

1) Feature extraction and matching: Firstly, extract feature points from a continuous image sequence; Then, feature points are described using feature descriptors such as SIFT, ORB, etc. Next, use feature matching algorithms to match feature points between adjacent frames;

2) Motion estimation: Assuming the feature points in the first image is (x_1, y_1), the feature points in the second image is (x_2, y_2), the internal parameter matrix of the camera is K, and the essential matrix is E. By matching feature points, a set of corresponding feature point pairs can be obtained. Then, the motion formula of the camera is restored by substituting it into the essential matrix shown in Equation 1.

$$k^T * [x_1, y_1, 1]^T * E * [x_2, y_2, 1] = 0 \quad (1)$$

3) Triangulation: Assuming that the pixel coordinates of the feature points in the first frame image is (x_1, y_1), in the second frame image is (x_2, y_2), the internal parameter matrix of the camera is K, the rotation matrix of the camera is R, the translation vector is T, and the coordinates of the feature points in the real world is $[X, Y, Z]$. By using the camera projection relationship, a system of equations can be established as shown in equations 2 and 3.

$$K * [R|t] * [X, Y, Z, 1]^T = [x_1, y_1, 1]^T \quad (2)$$

$$K * [R|t] * [X, Y, Z, 1]^T = [x_2, y_2, 1]^T \quad (3)$$

By solving the nonlinear equation system composed of equations 2 and 3 above, the coordinates of feature points in the real world can be calculated;

4) Speed calculation: Assuming the position of the feature points in the first frame of the image is $P_1 = [X_1, Y_1, Z_1]$, the position in the second frame of the image is $P_2 = [X_2, Y_2, Z_2]$, and the time interval between the two frames is Δt. By calculating the displacement of feature points in the real world, the camera speed can be obtained by using the following equation 4.

$$V = (P_2 - P_1) / \Delta t \quad (4)$$

Where,V is the velocity vector of the camera.

4.2. Calculation of Track Offset

The linear regression algorithm is used here for the fitting process [14] [15].

For a series of data points (xi, yi), there are equations 5 and 6 as follows

$$y = mx + b \quad (5)$$

$$E(m, b) = \Sigma_{i=1}^{N}(y_i - (mx_i + b))^2 \quad (6)$$

Among them, $\Sigma_{i=1}^{N}$ is the number of data points and $E(m, b)$ is the fitting error. Obtain the best fit line by minimizing $E(m, b)$. Finally, calculate the vertical distance using equation 7 to obtain the trajectory offset.

$$d = \frac{|m * x_{current} - y_{current} + b|}{\sqrt{m^2 + 1}} \quad (7)$$

4.3. Calculation of Coincidence Degree

The overlap between two vehicle identification frames is measured using the Intersection over Union (IoU), Also known as overlap rate or Jaccard coefficient.

Assuming there are two recognition boxes, the coordinates of the upper left corner of box A are (x_1A, y_1A), the coordinates of the lower right corner are, the coordinates of the upper left corner of box B are (x_1B, y_1B), and the coordinates of the lower right corner are (x_2B, y_2B), then the calculation method for the intersection area is shown in equation 8.

$$i\_area = max(0, min(x_2A, x_2B) - max(x_1A, x_1B)) * max(0, min(y_2A, y_2B) - max(y_1A, y_1B)) \quad (8)$$

Where i_area is the intersection area.

The calculation method for Union Area is shown in Equation 9.

$$u\_area = BoxA + Box\ B - i\_area \quad (9)$$

Where u_area is the union area.

By substituting the intersection area and union area into the calculation formula shown in Equation 10, the overlap degree of the two recognition boxes can be obtained.

$$IoU = (i\_area) / (u\_area) \quad (10)$$

4.4. Collision Detection Process

When the overlap and speed change between two vehicles exceed the threshold, the system will determine the occurrence of a collision accident, as shown in the overall collision detection process in Figure 4.

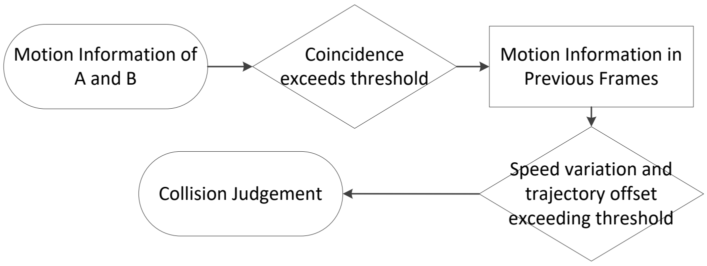

Fig. 4: Collision detection process

5. System Implementation and Testing

The collision recognition process for vehicle accidents is shown in Figure 5.

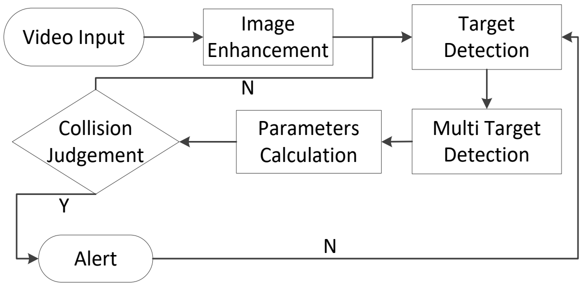

Fig. 5: Vehicle collision recognition process

It can be seen from figure 5 that, if it is determined that an accident has occurred, the system will give an intelligent alarm and store the accident video [16].

5.1. Testing on Sand Table

The following Figure 6 is a simulation test. By placing the remote control vehicle model in the camera scene, the system can automatically complete the recognition of the vehicle as shown in the left figure in Figure 6, and surround the appearance of the vehicle with a rectangular box.

Fig. 6: Simulation Test

During the process of vehicle movement, the system can continuously track the vehicle. As shown in the right figure in Figure 7, once the vehicle collides, the system will display a prompt message on the screen, reminding the operator to handle the accident.

Table 1 shows collision detection results in different parameters. The vehicle speed is the measured speed of the machine, and the result is rounded.

Table 1: Test Parameters and Results

Speed	Trajectory deviation(m)	Tracking Result	Collision Judgement
21	3.1	Correct	Correct
25	3.4	Correct	Correct
28	4.6	Correct	Correct
32	5.6	Correct	Correct

5.2. Comparison of Test Results

A large number of experimental statistics were conducted on the same dataset containing videos from different environments, using the methods proposed in this paper and other literature methods. The comparison results are shown in Table 2 below. From the statistical results, it can be seen that compared to other methods, the accuracy of collision testing using this method has been improved to a certain extent in various testing environments.

Table 2: Results Comparison

Environment	Accuracy	Accuracy in Ref. 3	False	False in Ref. 3	Loss	Loss in Ref. 3
Strong Light	95.4%	85.1%	3.7%	6.7%	0.9%	8.2%
Weak Light	94.7%	80.3%	3.6%	10.1%	1.7%	9.6%
Cloudy	93.6%	75.2%	5.1%	10.5%	1.3%	14.3%

6. Conclusion

This article designs a vehicle collision detection system that preprocesses images using a lighting enhancement model, and then uses the YOLO V5 model to complete vehicle detection; Combining Kalman filtering with Hungarian matching algorithm to achieve multi-target tracking function; By using the visual mileage calculation method to calculate the vehicle speed, as well as the trajectory deviation and overlap between vehicles, the occurrence of accidents can be determined based on whether the above parameters are abnormal.

7. Acknowledgement

We would like to acknowledge the invaluable help of my colleagues; and appreciate financial support from Jianghan University (Fund No. 2021yb053).

8. References

[1] Zhang Wenhai. Research on Obstacle detection and Road Recognition of Intelligent Vehicle based on vision [D]. Chongqing: Chongqing Jiaotong University, 2022.

[2] NAKAI Y, MIWA T, SHIGEMUNE H, et al. Four-dimensional collision detection and behaviour based on the physics-based calculation[J]. Expert Systems, 2023, 40(2): e12668.

[3] Wang Yibo. Based on Image Processing Traffic Accident Detection and Responsibility Judgment[D]. Xi'an: Chang'an University, 2022.

[4] Zhang Chenchen, Jin Hong. Research on Target Detection Based on Improved YOLOv3-Tiny[J]. Journal of Ordnance Equipment Engineering, 2021, 42(9): 215-218, 312.

[5] Han Zhenyang, Wang Xianlan. An improved algorithm for small object detection based on YOLOv5[J]. Electronic Design Engineering, 2023, 31(19): 64-67, 72.

[6] Chen Ruidong, Qin Huibin. Vehicle tracking algorithm based on multi-feature fusion and Kalman prediction[J]. Electronic Measurement Technology, 2023, 46(7): 32-38.

[7] Ao Bangqian, Yang Sha, Liu Xiaoyong, et.al. Target Tracking System Based on lmproved Camshift Algorithm[J]. Journal of Detection & Control, 2021, 43(6): 92-100.

[8] Lin Fei, Zou Ling, Zhang Cong. Fast Collision Detection Algorithm Based on Hybrid Hierarchical Bounding Box[J]. Computer Simulation 计算机仿真, 2023, 40(9): 454-457.

[9] Wang Leiyu, Han Xu, Hao Shijie. Low-light image enhancement model based on base-detail decomposition[J]. Journal of Hefei University of Technology(Natural Science), 2021, 44(10): 1339-1346.

[10] MORADI E, MOHSENI R. Parameters estimation of linear frequency modulated signal using Kalman filter and its extended versions[J]. Signal, Image and Video Processing, 2023, 17(2): 553-561.

[11] Li Jianguo, Zhang Rui, Wang Kai, et.al. Multi-Object Tracking Algorithm Based on Hungarian Matching and Kalman Filtering[J]. Automobile Applied Technology, 2022, 47(1): 45-50.

[12] LI D H, TAN S S, ZHANG J Z, et al. Hungarian method in a car-sharing system application research[C]//Advances in Artificial Intelligence and Security. Cham: Springer, 2021: 265-275.

[13] Li Shengjie, Xu Caiyi, Xing Meng, et. al. Vehicle speed measurement algorithm and performance analysis based on 3D object detection[J]. China Integrated Circuit, 2021, 30(5): 54-60, 76.

[14] Wu Yazhou. Research on Road Target Detection and Tracking Technology for Vehicle Collision Warning[D]. Changsha: Hunan University, 2021.

[15] Bo Ying. Vehicle Tracking and Re-Identification in Traffic Videos[D].Xi’an: Chang’an University, 2022.

[16] Dai Jinghua. Study on a Lane Line Detection Algorithm Based on Python[J]. Electronic Technology, 2022, 51(9): 52-54.