Real-time Detection of Vehicle Speed Based on Video Image

Genyuan Cheng[1], Yubin Guo[2], Xiaochun Cheng[3], Dongliang Wang[4], Jiandong Zhao[2,5]

[1]Tangshan Municipal Transportation Bureau, Hebei Province Tangshan, 063000, China
[2] School of Traffic and Transportation, Beijing Jiaotong University, Beijing, 100044, China
[3]Beijing National Day School, Beijing, 100039, China
[4]Tangshan No1Middle school, Hebei Province Tangshan, 063000, China
[5]Key Laboratory of Transport Industry of Big Data Application Technologies for Comprehensive Transport, School of Traffic and Transportation, Beijing Jiaotong University, Beijing, 100044, China
*corresponding author's email: zhaojd@bjtu.edu.cn

Abstract—**With the continuous development and improvement of Intelligent Transportation System, more and more attention has been paid to the real-time and accurate speed information detection. Video vehicle speed detection based on machine vision has attracted the attention of the researchers due to its practical convenience and other advantages. In this paper, we propose a target tracking method based on video image feature matching vehicle to simplify the algorithm complexity and obtain high accuracy. The background subtraction method based on KNN algorithm is used to identify vehicle targets and obtain good initial vehicle characteristics. Experimental results show that the method has high real-time and the relative error of vehicle speed detection can be controlled at about 5%.**

Keywords- Image processing; Target tracking; The speed test

I. INTRODUCTION

Speed measurement plays a very important role in traffic flow information collection. Real-time speed information collection is also a hot issue in the field of intelligent transportation. The realization of Intelligent Transportation System (ITS) is inseparable from real-time speed information collection [1].

At present, speed measurement methods are mainly divided into two categories. One is based on hardware, which mainly includes laser speed measurement, radar speed measurement, etc. Above methods require professional equipment, which is expensive to install and maintain and their application has limitations. The other is based on software, mainly including video-based velocity measurement, and adopts image processing technology to process the traffic flow video, so as to achieve the purpose of collecting all kinds of traffic information. As a promising detection method, this method provides rich traffic flow information and has many advantages that other methods are difficult to match [2].

The problem of real-time speed detection based on video image can be divided into two aspects: moving target detection and moving target tracking. At present, there are three main methods of target detection. The frame difference method can maintain the motion path of the moving target in two consecutive frames of images and eliminate the interference of unstable factors. The biggest limitation of this method is that it cannot detect stationary and slow-moving targets. The most critical step of background difference method is background modeling, which extracts accurate and steady background images, and uses background images to separate moving objects from original frames. The optical flow method reflects the changes of pixel points in the time domain of the imaging plane coordinate system by calculating the optical flow value of video image pixel points, and then finds the corresponding relationship between adjacent frames, and calculates the image displacement of the tracked target and other information. Since the basic assumption of the optical flow method is that the brightness is constant and short movement, it is no longer applicable when light changes or the time interval is too long [3]. Most of the moving target tracking is based on the principles of motion estimation, probability distribution, feature matching, etc., and the calculation is generally large, which cannot meet the real-time requirements of video speed detection.

Based on the above analysis, this paper mainly explores and improves the tracking method of moving targets. Based on the feature that the target contour features of adjacent frames of video image do not change much, a centroid distance matching method is proposed for vehicle tracking. By calculating the target centroid coordinates of two adjacent frames and setting the distance threshold for filtering, target matching is achieved, so as to achieve the purpose of tracking target vehicles.

II. VIDEO METHOD OF VELOCITY MEASUREMENT

A. Video velocity measurement principle

The main principle of the video-based vehicle speed detection method is that the vehicle movement position is removed to the vehicle movement time.

The vehicle motion time can be directly obtained through image frame rate, while the actual displacement cannot be directly obtained, which needs to be obtained through camera calibration. In other words, the geometric model of camera imaging is established, and the mapping relationship between image coordinates and the actual three-dimensional road coordinate system is solved, so as to obtain the actual displacement [4].

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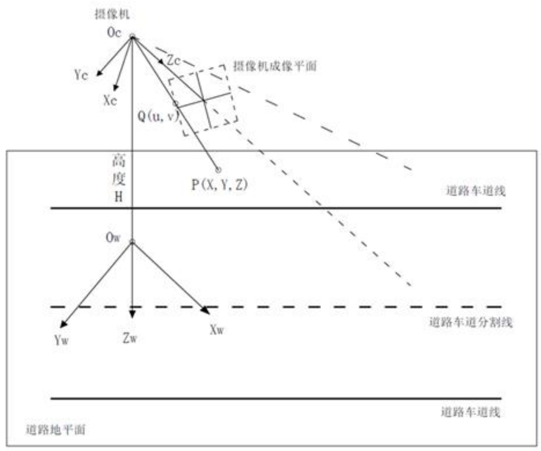

Figure 1. Camera imaging model

Before solving, the target vehicle must be located and tracked. In the stage of moving target positioning, based on the relatively stable background picture of monitoring video, we realized the preliminary foreground (i.e. moving vehicle) detection through background modeling.

B. Moving target detection stage based on KNN background modeling

K-nearest Neighbor (KNN) classification algorithm is one of the simplest machine learning algorithms. The idea of this algorithm is: if most of the k most similar samples in the feature space belong to a certain category, then the sample also belongs to this category [5]. That is to say, the category (foreground or background) of the sample to be classified is determined only according to the category of the nearest k samples.

Applied to the background segmentation can understand like this: in the scene for the current frame image of a pixel values, compared with the K historical values of the pixel, if the difference between pixel values within a specified threshold, argues that the new is matching pixel value and historical value, return to potential classes, After all historical information has been compared, if the number of matches exceeds the set threshold, then the new background pixel is classified as potential background points.

In python and OpenCV environment, use cv2.createbackgroundsubtractorKNN() to realize KNN background function, the effect shown in Fig.2 on the left.

In OpenCV, the cv2.findcontours () function can find the contours of a binary graph. The contours return an array of coordinates of the boundary points of the object, and the cv2.boundingrect () function finds the straight rectangular box surrounding the target object.

The detection results of moving objects obtained through contour search, screening and drawing are shown in Fig.2 on the right.

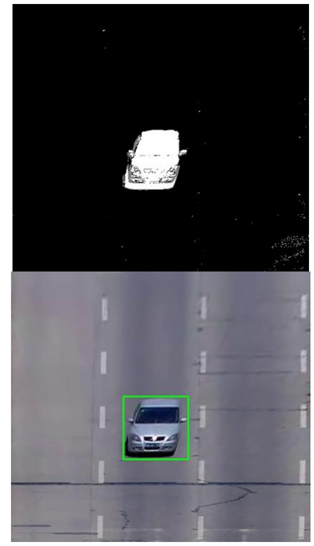

Figure 2. Result of moving target detection

C. Matching tracking method based on Centroid Distance

For the extracted moving target, how to track it is also an important step that directly affects the speed measurement results. There are many ways to track the moving target, but in order to track the vehicle in real-time monitoring video and calculate the speed, it is necessary to have a tracking method with small calculation amount and guaranteed accuracy. Therefore, in this paper, the centroid point represents the vehicle, and according to the characteristics of the small distance offset of the centroid point in the adjacent image sequence, whether the selected target is the same vehicle is judged, and the speed is calculated at the same time.

1) Centroid Distance matching principle

Moving object matching is to find the same moving object by matching in different frames of images. According to the characteristics of video of road monitoring, the centroid matching method is applied in this paper.

a) Calculation of the centroid point of moving vehicles

The centroid point of moving vehicle is obtained from the geometric moment of image. The geometric moment of image can be divided into zero order moment, first order moment and second order moment. In this paper, only the area and the centroid point are calculated, so zero order moment and first order moment are used only. The calculation formulas are shown in equations (1), (2) and (3).

$$M_{00} = \sum_{I}\sum_{J} V\left(i,j\right) \tag{1}$$

$$M_{10} = \sum_{I}\sum_{J} i \times V\left(i,j\right) \tag{2}$$

$$M_{01} = \sum_I \sum_J j \times V(i,j) \quad (3)$$

Represents the gray value of the image at the point. Thus, when the image is a binary image, there is only 0 (black) and 1 (white), M_{00} is the sum of the white areas in the image, namely the area of the binary image. M_{10} is the sum of x coordinate values in all white areas of the image. Therefore, the formula for calculating the centroid point of the first moment is shown in equation (4).

$$x_c = \frac{M_{10}}{M_{00}}, y_c = \frac{M_{01}}{M_{00}} \quad (4)$$

b) Centroid Distance matching principle

The purpose of this paper is to track and analyze the vehicle targets of each frame or several frames of video sequence. However, the moving distance of the same moving vehicle target in adjacent frames is not large, and the target area changes little. Based on such characteristics, the simple calculation method of centroid matching can get good results. For target selection, the target vehicle with the largest area detected before is selected in this paper, and its displacement distance is obtained through centroid distance matching, so as to facilitate accuracy comparison.

c) Description of threshold value of Centroid Distance

Minimum centroid distance: as the vehicle just enters or leaves the detection area, its detection box size will change to some extent, so that the centroid distance will change very little. By setting the threshold of minimum centroid distance, most of the errors caused by small detection speed can be removed.

As shown in Fig.3, the target in the red box is entering the detection area, and its detection box size is changing constantly.

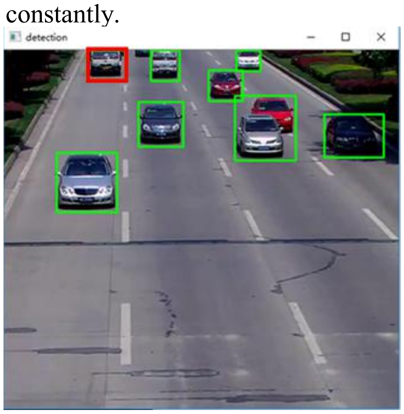

Figure 3. The source of minimum distance error

Maximum centroid distance: this method takes advantage of the small distance of the same target vehicle in adjacent frames. When multiple targets are detected, different vehicles may misjudge the tracking. As the distance between adjacent centroid of different vehicles will be much larger, such errors can be avoided by setting a threshold of maximum centroid spacing.

2) Tracking method design

The principle of the tracking method in this paper has been introduced above, and the specific algorithm steps are as follows:

a. Selects the vehicle target detection box detected by the current frame image.

b. Selects the vehicle target detection box detected in the next image frame.

c. Calculates the centroid distance of the detection box of adjacent frames, and determines whether it is within the threshold range of the minimum and maximum centroid distance. If yes, it means that the detection box in these two frames tracks the same vehicle, then the two points will be displayed, and the distance will be converted into actual displacement and put into a set. If it is not within the threshold, it means that the two image detection boxes are not tracking the same vehicle or the vehicle is entering and leaving the speed measuring area, then it will not be displayed and the distance will be abandoned.

d. Until video frames can be not read, the algorithm is finished and the tracking is completed.

3) tracking results

The algorithm in this paper is implemented by programming python and OpenCV environment, and finally the result of trace display as shown in Fig.4 is obtained.

Figure 4. Schematic diagram of centroid distance matching tracking results

4) speed calculation

The speed calculation requires the actual displacement of the vehicle, while the displacement measured in the previous section is the pixel displacement in the picture. In this section, the pixel displacement is converted into the actual displacement, and the interframe time is found to calculate the speed.

The actual displacement calibration of vehicles refers to the national standard "road traffic signs and lines" (GB51038_2015) : when there are two or more carriageways in the same driving direction, the lane dividing line shall be drawn and the lane dividing line shall be white dotted line. For example, the size of the highway lane dividing line is shown here (the picture is from the road traffic signs).

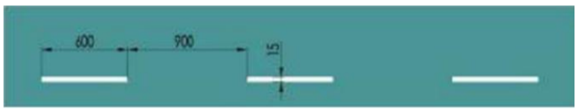

Figure 5. Diagram of highway lane standards

It can be concluded that the general road, the road lane layout of the uniform provisions. According to this figure, the conversion from pixel distance to actual distance can be completed.

III. THE EXPERIMENTAL RESULTS

The experimental system platform in this paper is based on the Windows 10 operating system and uses python3.7 and OpenCV for programming.

OpenCV (Open Source Computer Vision Library) is an Open Source Computer Vision and machine learning software Library. We can use OpenCV to process images, videos and other content efficiently and conveniently.

A. *Scene Selection*

In this paper, four specific scenarios are selected for video speed measurement, as shown in Fig.6.

Figure 6. Experimental scene

B. *Experimental Procedures*

The manual speed measurement process is as follows: a fixed length detection section is set in video, and the results are averaged and the speed is calculated through multiple times of timing by multiple people. (as shown in Fig.7 on the left)

As the speed measurement results in this paper are relatively short and close to instantaneous speed, the average speed of vehicles in the speed measurement section is taken as the machine speed measurement results. (as shown in Fig.7 on the right)

Figure 7. Experiment procedure

C. *Comparison of experimental results*

The four experimental results were compared and analyzed horizontally, and the specific data details were shown in Table 1.

Table 1 Experimental information

Test number	Position	Shaking	Shadow	Light	Error/ %
1	Top	Stable	No	Medium	4.125
2	Both sides	Stable	No	Weaker	3.948
3	Inter-section	Shaking	No	Medium	8.973
4	Top	Stable	Yes	Strong	4.398

The four experiments were compared and the conclusions were summarized as follows:

a. Surveillance camera should be installed at the top of the road or on both sides of the road, that is, the camera is facing the front of the car or parallel to the car. In this way, complete and stable vehicle information can be captured.

b. In order to achieve accurate speed measurement, the shooting picture must be stable, or it will have a bad effect on the background modeling.

c. The intensity of light affects the speed measurement accuracy. The strong light has no effect on some black or dark cars, but for white and red, the reflective condition is more serious, and the subsequent image processing of the vehicle detection is very demanding., and it is easy to see the disconnection between the head and the body.

d. Shadow has little influence on the speed measurement accuracy. The shadow can measure the speed with the vehicle as a whole, and the state changes of its adjacent frames are very small.

IV. CONCLUSIONS

A method based on KNN algorithm background modeling is proposed to extract moving targets and apply centroid distance matching method to achieve target tracking, so as to calculate vehicle speed.

First, pre-process the video image sequence video image sequence. Then, the background modeling method based on KNN algorithm is adopted for subsequent background elimination to realize target and contour detection. Based on the feature that the target contour feature of adjacent frames of video image does not change much, the centroid distance matching method is adopted for vehicle tracking. The centroid distance matching tracking method is proposed and designed in this paper. Experimental results show that the relative error of speed detection can be controlled at about 5%, and can meet the real-time requirements of video monitoring speed detection.

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