Vehicle Forecast Track Based on Virtual Detector

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Abstract. Vehicle monitoring technology based on the video image due to its features of easy maintenance and easy implement is concerned in recent years. Vehicle tracking is one of the key technologies to achieve video vehicle monitoring. How to achieve real-time vehicle tracking is the key and difficult problem at home and abroad. A method of Kalman tracking based on virtual loop is proposed in the paper. Two parts about vehicle presence detection and vehicle forecast tracking are introduced in this paper. Experimental results show that this method in the fast-path scenarios can effectively achieve vehicles tracking, fully meet the system requirements and have high practicality.

Introduction

Since 1980s, with the development of science and technology and the progress of society, the number of cars and urban population has increased more and more and the capacity of Road Netcom has been unable to meet the demand of growing traffic. Traffic congestion, traffic jams and accidents have become increasingly serious. To solve these problems, control traffic density and avoid traffic congestion, powerful traffic management tools should be needed. However, man-management systems, due to its low efficiency and high cost, have obviously suited to the traffic situation no longer. With the rapid development of multimedia technologies, video image has become one of the mainstreams of information dissemination. Therefore, vehicle monitoring system based on video image is the traffic trends of world road. In order to achieve video traffic monitoring, real-time and stability of vehicle tracking are two key factors.

Vehicle forecast tracking based on virtual loop is proposed in the paper. This method only needs to extract the background image, and then set the virtual loops to detect the state of vehicles, through predicting and tracking the state of the virtual loops to achieve the purpose of tracking vehicles. The test results show that the method can effectively improve the real-time and stability of vehicle tracking, thus proving the validity of the method.

Introduction and Process of Vehicle Tracking Method

In traffic monitoring systems, the purpose of vehicle tracking is to determine the trajectory of vehicles. That is to say, establishing a correspondence relation between foreground objects and tracking moving targets.

In the video sequence, the time interval between two adjacent images is small, the movement of vehicle is unlikely to mutate. Therefore, we can consider that the tracking window size and location of the target vehicle change little. The centroid of target vehicle and work window size can be considered as the characteristic values to track. Then, Kalman filter is used to forecast the next time state of target vehicle and narrow the target range. Using the centroid of target vehicle and work window size as the characteristic values to carry out track, the measurement is obtained when making matching at the same time. And then update the motion model through Kalman filter and eventually form a tracking chain, the trajectory of vehicle is obtained. The algorithm flow as shown in Figure 1.
Detection of Vehicle Presence

The first step of vehicle forecast tracking based on virtual detector is to detect the presence of vehicles.

Set of Detection Loops

In order to achieve vehicles detection more accurate, three adjacent detection loops formed a detector is used in this article, as shown in Figure 2.

![Figure 2. Illustration of Vehicle Existing Detector.](image)

In Fig 2, ①, ② and ③ are three adjacent detection loops. Because the three detection loops are apart close, they have certain relevance.

From the time domain, assuming the maximum speed of vehicles are 150km/h on the road, for the video images of PAL format, 25 frames per second, that is the sampling time for each frame is 40ms. Vehicles at this time may move a maximum distance of 1.67m. Usually, the length of a small vehicle is around 4m. In other words, even if the vehicle has reached the highest speed, the image frames it stays on the detection line will be greater than one. Speaking from space, when the vehicles move, there must be certain distance between them. Suppose there are vehicles whose speeds are 150km/h, their distance should be at least 10m above. For signal of PAL format, the sampling frequency is 25Hz and the time interval of frames is 40ms, vehicles move 4m distance too more. According to the length of common cars, the length of L1 in Figure 2 is set to 4.5m; the length of L2 is set to 5.0m. The rectangular box on lane 3 is loop ①, as shown in Figure 3.

First of all, the characteristic parameters of background within the detection region are recorded as P_b. Then to strike the same characteristic parameters P_n for the follow-up video image frame, and
set a threshold $T$. When $|P_n-P_b|>T$, the state of this frame is considered as 1. For a single detection loop, set the state of three consecutive frames as State(i-1), State(i), State(i+1). If the states of any two frames are one, it finds that a vehicle is present within this area. Taking three consecutive images as the judgments of vehicle presence, the purpose is to minimize the error generated by the noise, while ensuring the accuracy of information.

![Figure 3. Scene of Vehicle Existing Detector.](image)

**Suppression of Vehicle Shadow**

In the process of solving whether vehicle is present, it will be impacted by the shadow of vehicle. For example, as shown in Figure 3, the shadow of vehicle which is on lane 2 will drop on the lane 1; the shadow of vehicle which is on lane 4 will drop on the lane 3. If the shadow is not restrained, all of the four lanes will detect the existence of vehicle. Of course, the test of lane 1 and 3 will cause false detections. Therefore, the shadow must be suppressed. The shadow suppression algorithms are mainly as follows: the shadow suppression based on edge detection $[1][2]$, the shadow suppression based on three-dimensional model $[3]$, the suppression method based on RGB color space $[4]$ and the suppression method based on HSV color space $[5][6]$. The shadow suppression algorithm based on the HSV space which is described in the literature $[6]$ is used in this paper.

$$
SP(x,y) = \begin{cases} 
1 & \text{if } \alpha \leq \frac{I^H(x,y)}{B^H(x,y)} \leq \beta \land (I^V(x,y) - B^V(x,y)) \\
& \leq \tau_s \land (I^S(x,y) - B^S(x,y)) \leq \tau_H \\
0 & \end{cases}
$$

(3.1)

In the formula (3.1), $SP(x,y)$ is shadow mask. $SP(x,y)$ is 1 means that the pixel is shadow. $I^H(x,y), I^S(x,y), I^V(x,y)$ and $B^H(x,y), B^S(x,y), B^V(x,y)$ are H,S,V components of the pixels present values I and background values B. Threshold $\alpha$ and $\beta$ meet $0 < \alpha < \beta < 1$. Threshold $\tau_s$ should be less than zero. Threshold $\tau_H$ should select with experience.

![Figure 4. Effect of Shadow Elimination.](image)

Figure 4 is the effect figure of shadow suppression. As can be seen from Figure 4(a), when vehicles pass through detection loops, after restraining shadow, the shadow area inside the loop shows the background image, but the vehicle information was not affected. That is to say, under the circumstance of shadow suppression, the vehicle information is well maintained. In the Figure 4(b), when only shadow passes through the detector, there is absolutely no shadow pixel inside the loop.
It is equivalent that there are no objects passing through the detector loop, the detection results are not affected by shadow.

**Vehicle Forecast Tracking**

When one vehicle passes through an area, the state of the virtual loop will be from 0 to 1, the state $X$ of the virtual loop $1$, $2$, $3$ and state $Y$ of testing line $1$, $2$, $3$ are as shown: $X = \begin{bmatrix} x_1 & x_2 & x_3 \end{bmatrix}^T$ and $Y = \begin{bmatrix} y_1 & y_2 & y_3 \end{bmatrix}^T$.

**The Establishment of Tracking Model**

Vehicle forecast tracking model based on virtual detector real-time detect and track vehicles according to the state of the virtual loops. The states of $X$ and $Y$ are $X = \begin{bmatrix} x_1 & x_2 & x_3 \end{bmatrix}^T$, $Y = \begin{bmatrix} y_1 & y_2 & y_3 \end{bmatrix}^T$. Their values obtain from the collection of $\{[1 \ 0 \ 0]^T,[0 \ 1 \ 0]^T,[0 \ 0 \ 1]^T,[1 \ 1 \ 0]^T,[0 \ 1 \ 1]^T,[1 \ 1 \ 1]^T\}$. In which, 1 show that the vehicle exists, 0 means there are no vehicles in the area.

The state equation of tracking model:

$$S_{k+1} = \Phi S_k + \Gamma \xi_k \quad (4.1)$$

Defined observation model:

$$Z_{k+1} = \Theta S_{k+1} + \eta_{k+1} \quad (4.2)$$

In the formula (4.1) and (4.2), $S_k$ are the five-dimensional state vector and its expression as shown in formula (4.3).

$$S_k = [X_k \ Y_k \ P_k \ V_k \ L_k]^T \quad (4.3)$$

Observation vector $Z_{k+1}$ is:

$$Z_{k+1} = [X_{k+1} \ Y_{k+1}]^T \quad (4.4)$$

In the formula (4.3), $P_k, V_k, L_k$ are the position, velocity and type of vehicles. And both of them are used as $X_k$ and $Y_k$. As shown in the formula (4.5):

$$\begin{align*}
(1) \quad P_K &= M_p X_K + N_p Y_K \\
(2) \quad V_K &= M_v (X_K K) + N_v Y_K \\
(3) \quad L_K &= M_L X_K + N_L Y_K 
\end{align*} \quad (4.5)$$

In the formula (4.5), $M_p, M_v$ and $M_L$ are the vehicle position of detection loop, velocity and algorithm of type; $N_p, N_v$ and $N_L$ are the vehicle position of detection loop, velocity and algorithm of type.

**Determine the Logical Relationship**

Under the circumstance of vehicles presence at this region, that is to say, the state of $X$ and $Y$ are known. The values of $P$, $V$ and $L$ can be obtained according to certain logical relations. From formula (4.5), the values of $P$, $V$ and $L$ are determined by $X$ and $Y$. For the $P$, which is the real-time location of vehicles, is divided into horizontal and vertical. Vertical refers to the state of $Y$, which can determine the lane information; Horizontal refers to the state of $X$, which can obtain the vehicle position inside the detection loops. In the formula (2) of (4.5), the means of $V_K = M_v (X_K K) + N_v Y_K$ are as follows: $N_v Y_K$ indicates the speed detection on a lane; $X_K K$ records the number of video frames when loops change; $K$ is the number of video frames in video.
stream. Then the speed information can be obtained through velocity operator $M_{v}$. The expression of velocity operator $M_{v}$ is as follows:

$$
M_{v} = \begin{bmatrix}
    s_{1}/T & 0 & 0 \\
    s_{12}/T & s_{12}/T & 0 \\
    0 & s_{2}/T & 0 \\
    0 & s_{23}/T & s_{23}/T \\
    0 & 0 & s_{3}/T
\end{bmatrix}
$$

(4.7)

In the formula (4.7), $T$ means the time interval of video adjacent frames; $s_{1}$, $s_{2}$, $s_{3}$ are the width of established detection loops; $s_{12}$, $s_{23}$ are the distance between the loops.

**Experimental Results and Error Analysis**

Under the circumstances of small traffic flow and smooth flow traffic, this experiment is tested. In order to meet the general requirements, the traffic flow is not large, and there is generally no traffic jam phenomenon, meeting the test requirements.

Table 1. Effect of vehicle arithmomemter.

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A-Traffic Lane, B-Preliminary Analysis of Errors, C-Further Analysis of Error, D-Actual Number, E-Detection Number, F-Accuracy Rate, G-Number of Less Detected, H-Number of More Detected, I- Number of Total Error, J- Total Error, K- Total.

Note: Less detected means that the detector can not detect when a vehicle passed; more detected means that the detector is false.

Table 1 is the test results of vehicle count. In which, the values of accuracy can be calculated by the formula $1 - \frac{|Actual Number - Detection Number|}{Actual Number} \times 100\%$. The values obtained are not real test results, because there has a situation of offsetting between less detected and more detected in the testing process. The errors must be done further analysis. Therefore, the number of less detected and more detected is listed in the table. Take the data in lane 1 as an example: Through manual counting in the process of detecting vehicles by video detector, the number of less detected is 4; the number of more detected is 2. Detector shows the number of vehicles after offsetting between less detected and more detected. The end result is 74, that is, the number of detector malfunction is 6 when actual number is 76. Total number of errors record as 6. The calculations of total errors are obtained by $(Total Number of Errors / Actual Number)$.

Table 2. Results of velocity and figure.

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<td>K</td>
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In Table 2, the accuracy rate of a simple vehicle is more than 90%, meeting the application requirements.

As can be seen from Table 4.1 and Table 4.2, the overall level of errors is within an acceptable range. The main factors that cause errors are:

1. The effect of vehicle shadow cause more detected;
2. The blocking among vehicles cause less detected;
3. Vehicles move cross-road or change road suddenly;
4. Complex shape of special vehicles results in more detected.

Conclusion

A method of prediction tracking based on virtual loop is proposed in the paper. And details of its theoretical derivation and implementation process are given. Finally, tracking method is tested. The test data shows that the method is effective and has application value in vehicle detection system.

References


