THE JAYWALKER DETECTION BASED ON MOTION PATH ANALYSIS

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Abstract: Jaywalk is the most common urban traffic violation, so an intelligent jaywalker detection method is presented in this paper. The method analyses and detects jaywalker's abnormal behavior against traffic rules. Firstly, the motion object is segmented based on the background difference method, and pedestrian is recognized from vehicle according the height-width ratio. Secondly, the pedestrian's motion path is obtained through the linear predictive tracking algorithm. Then the pedestrian motion path is simplified to the line set through linear fitting, and the motion direction is calculated. Finally, the jaywalker is detected according the angle between the pedestrian's motion direction and road direction. The experiment shows that the method can detect the jaywalker effectively in short time, and it is suitable to use in real time monitoring.
Key words: *pedestrian detectio, jaywalker detection, object tracking, linear fitting*

1 Introduction

In Chinese urban traffic system, the traffic accident is a serious traffic problem, and a large of these due to pedestrian's abnormal behavior. So lots of works have been done about the pedestrian abnormal behavior detection.

There are two ways to detect the pedestrian abnormal behavior, one is based on the model, and the other is based on clustering. Model-based methods have been widely used in recent years, such as the 2D Body-model (Hogg D,1983) is used to describe the human action based on the time-dependent human posture which is obtained from each frame, but with the change of the visual angle, this method can't describe the human structure accurately, because the joint of human body is covered in the picture. Wang (Wang W, 2010) sets up a height-width ratio model based on the periodical change of pedestrian height-width ratio to detect the abnormal behavior such as the squat, which does not comply with the model, but the jaywalk complies with the model so this method can't detect the jaywalker. The clustering methods divided video into several parts, and use the vectors to describe the features in every part，then detect the abnormal behavior based on similarity measurement. Zhong (Zhong H, 2004) seeks a correspondence relationship between prototypes and video segments which satisfies the transitive closure constraint to detect the abnormal behavior. Hu (Hu Z L, 2008) classifies the motion direction of the object's block to detect the abnormal behavior. The clustering methods usually are complex in algorithm and can't meet the requirement of real-time detection.

To deal with disadvantages in algorithm complexity and robustness and to detect jaywalker in real-time, an intelligent jaywalker detection method, which detects jaywalker's motion feature against traffic rules, is presented in this paper. First, the pedestrian motion path is obtained through the motion object segmentation, pedestrian recognition and pedestrian tracking. Second, the pedestrian's motion direction is obtained through linear fitting. Finally, the jaywalker is detected according the angle between the pedestrian's motion direction and road direction.

2. Pedestrian recognition and tracking

2.1 Pedestrian detection and recognition

When the camera is stationary, the background difference method is an efficient method to segment the motion object. The flow chart of pedestrian detection and recognition is shown in figure 1.

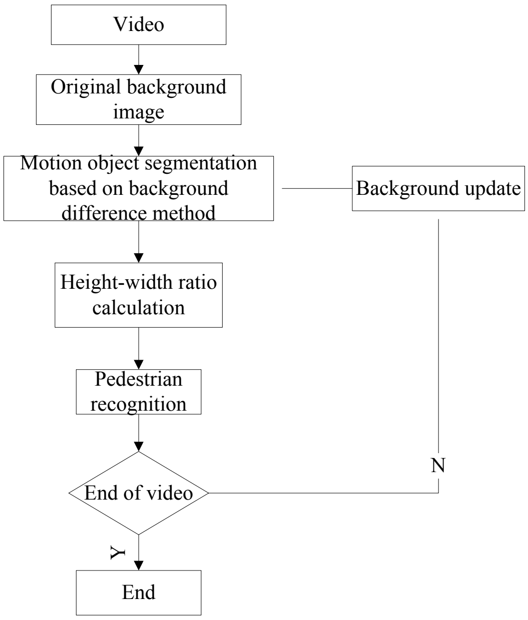


Figure 1. The flow chart of pedestrian detection and recognition

The original background image can be obtained by the median filter. The median filter can be written as:

$$B_k(i,j) = Middle(I_k(i,j)) \qquad (1 \le k \le 50) \tag{1}$$

where $I_k(i,j)$ is the gray level of point (i,j) in k^{th} frame.

To gain a robust background with respect to the changes in illumination, the paper uses the Surendra method (Wang Z Q, 2008) to update the background. The core thought of this method is to update background in the motion region and keep the same in other region in each frame. The method can be written as:

$$B_k(i,j) = \begin{cases} B_{k-1}(i,j) & (W_k(i,j)=1) \\ (1-\alpha)I_k(i,j)+\alpha B_{k-1}(i,j) & (W_k(i,j)=0\ ) \end{cases} \quad (2)$$

where $B_{k-1}(i,j)$ is the gray level of point (i,j) in old background; $W_k(i,j)$ is the gray level of point (i,j) in the binary image of the difference image.

The motion objects which are extracted by the background difference method include pedestrian and vehicle, so the pedestrian recognition is necessary. By contrasting the pedestrian with the vehicle, it is obvious that the height-width ratio of the pedestrian is different from vehicle. The object's height-width ratio ρ ($\rho = H/W$) is defined by the height-width ratio of the object's outside rectangular, and calculated every five frames.

There are some results for a walking pedestrian, a running pedestrian and vehicles in a real video. The height-width ratio of the walking pedestrian is listed in table 1, and it ranges from 2.13 to 3.76. The height-width ratio of the running pedestrian is listed in table 2, and it ranges from 1.93 to 2.79. The height-width ratio of the vehicle is listed in table 3. ρ_3 is the height-width ratio of the small car, and it ranges from 0.73 to 0.83. ρ_4 is the height-width ratio of the large car, and it ranges from 1.09 to 1.22.

Table 1. The height-width ratio of the walking pedestrian

Frame	14	19	24	29	34	39	44	49	54	59
ρ_1	2.42	2.18	2.13	2.25	2.52	2.90	3.7	3.76	3.36	3.31

Table 2. The height-width ratio of the running pedestrian

Frame	12	17	22	27	32	37	42	47	52	57
ρ_2	2.7	2.42	2.2	1.96	1.93	1.97	2.06	2.26	2.72	2.79

Table 3. The height-width ratio of the vehicles

Frame	15	20	25	30	35	40	45	50	55	60
ρ_3	0.83	0.79	0.8	0.74	0.8	0.81	0.74	0.73	0.83	0.78
ρ_4	1.12	1.14	1.1	1.09	1.12	1.12	1.14	1.11	1.22	1.2

There is marked difference between height-width ratios of pedestrian and vehicle, so it is easy to distinguish pedestrian and vehicle using a threshold.

2.2 Pedestrian tracking

In order to obtain the pedestrian motion path, it needs to track pedestrian. Pedestrian tracking includes three steps.

First, linear predictive algorithm is used to predict the pedestrian position. According to the continuity of the pedestrian's motion in time and space and the pedestrian's low speed in the detection area, the linear predictive algorithm is suitable to predict the pedestrian position. The three-point linear predictive algorithm is used here, and it is described in the following formula (3).

$$f'_{k+1} = 2f_k - f_{k-1} + \sigma_k \quad (k = 2,3,\cdots) \tag{3}$$

where f'_{k+1} is the pedestrian's prediction position in the $(k+1)^{th}$ frame, f_{k-1} and f_k is the pedestrian's real position in the $(k-1)^{th}$ frame and in the k^{th} frame. The error parameter σ_k of the linear predictive algorithm can be written as:

$$\sigma_k = \begin{cases} 0 & (k=2) \\ \dfrac{\sum_{i=3}^{k} d_i}{k-2} & (d_i = f_i - f'_i,\ k = 3,4,\cdots,N) \end{cases} \tag{4}$$

where d_i is the difference between prediction position and real position in the i^{th} frame.

Second, the cost function (Li X, 2005) of candidate objects in next frame is calculated. There may be more than one candidate objects in the predicted region. For getting best match, each candidate object will be calculated cost function value, which means the similarity between the candidate object and tracked object. The less the value is, the more similar the two object is. For the object i in the k^{th} frame, each candidate object in the $(k+1)^{th}$ frame will be substituted to the formula to calculate the value. The cost function is showed in the following formulas.

$$V(i,j) = \alpha D(i,j) + \beta H(i,j) + \gamma A(i,j) \tag{5}$$

where $D(i,j) = \sqrt{(X_k^i - X_{k+1}^j) + (Y_k^i - Y_{k+1}^j)}$, $H(i,j) = \left|G_k^i - G_{k+1}^j\right|$, $A(i,j) = \left|S_k^i - S_{k+1}^j\right|$. (X_k^i, Y_k^i), G_k^i and S_k^i are the centroid ordinate, average gray level and area of the object i in the k^{th} frame; $D(i,j)$, $H(i,j)$ and $A(i,j)$ are distance, average gray level difference and area difference between the object i in the k^{th} frame and the object j in the $(k+1)^{th}$ frame. α, β and γ are empirical values.

Third, the object position is made sure. The object j, which makes the cost function has the minimum value in all candidate objects, is considered as the same object of object i in the $(k+1)^{th}$ frame. The position of object j will be recorded to update the pedestrian's motion path.

3. Jaywalker detection

There are four steps to finish jaywalker detection.

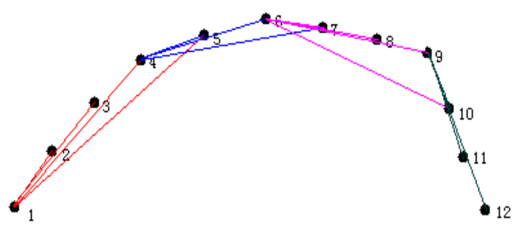
First, the pedestrian motion path is fit to one line or several lines through the linear fitting method. For example, there are 12 points in the pedestrian motion path. Some parameters are defined in Cartesian coordinate system whose origin is the left bottom point of image. K_{ij} (i,j ranges from 1 to 12) is the slope of the line between point i and point j. P_i is the start point of the line. K_i is the slope of the line which the start point is point i. NUM_i is the number of the points which are in the same line. The process of the linear fitting is following:

(1) i=1， j=2; Make a line from point i to j; K_i=K_{ij}; NUM_i=1.

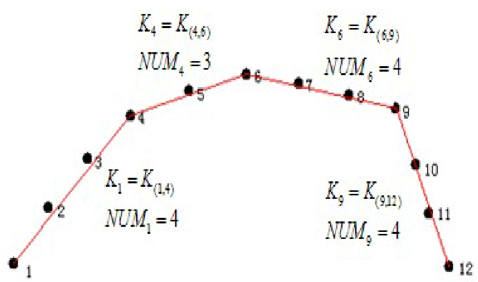
(2) j=j+1; Calculate the difference $D=|K_{ij}-K_i|$. If D is less than the threshold D_T, K_i=K_{ij}, NUM_i++, and repeat (2) ; if D is more than threshold, turn to (3); else if j>12, end.

(3) i=j-1, j=i+1; Make new line whose start point is P_i; K_i=K_{ij}; NUM_i=1 ; and turn to (2).

The process is shown in Figure 2(a), where same color lines mean they are fitting in one line. The result is shown in Figure 2(b), where 12 points in the pedestrian motion path are simplified to 4 lines. At the same time, slope and number of the points in each line are obtained.



(a)



(b)

Figure 2. The process and results of the linear fitting method

Second, pedestrian motion direction is found. Consider that the line which has few points can't indicate the direction of the pedestrian motion, the typical line will be searched according to NUM_i. If NUM_i is less than an experience threshold T, the line will be abandoned, else will be kept. The typical line is the one which has maximum points in all reserved lines. The slope K_i of the typical line is used to indicate the pedestrian motion direction.

Third, the angle θ between the pedestrian motion direction and the road direction is calculated according formula (6).

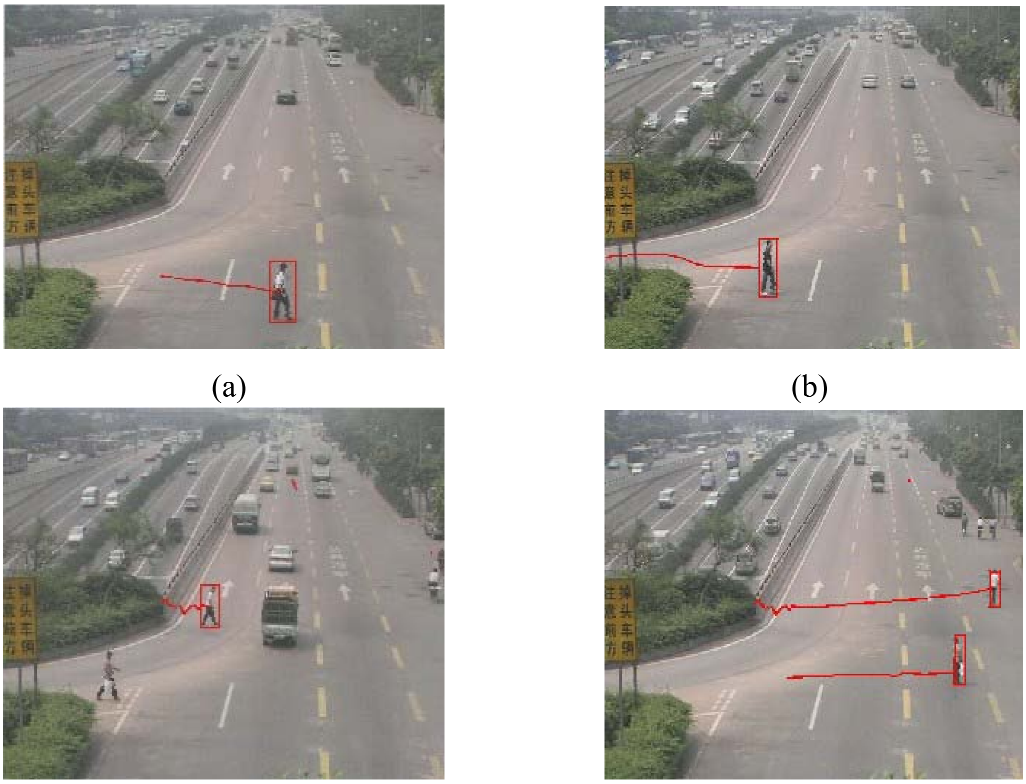
$$\theta = \arctan\left|(K_1 - K_2)/(1 + K_1 K_2)\right| \qquad (6)$$

where K_1 and K_2 are the slopes of pedestrian motion typical line and road. θ ranges from 0°to 180°.

Forth, jaywalker is detected according the angle θ. According the traffic rules, it is a fact that the angle between the jaywalker motion direction and road direction ranges from 45°to 135°. So, if $45° < \theta < 135°$, the pedestrian is a jaywalker; else, the pedestrian is a normal pedestrian.

4. Experiment result and analysis

The videos used in the experiment are real-time monitoring videos at a road in Guangzhou. They are D1 format, unpressed AVI files. In these videos, the pedestrian is not sheltered from the other pedestrian or vehicle. Some results are shown in Figure 3.



(a) (b)

(c) (d)

Figure 3. The result of the jaywalker detection

In figure 3, the line is the pedestrian motion path which is the trajectory of the centre of pedestrian's outside rectangle; the rectangle indicates the detected jaywalker. Figure 3(a) and figure 3(b) are the results of the jaywalker detection when there are few vehicles on the road. Figure 3(c) is the result of the jaywalker detection when there are many vehicles on the road. Although vehicles influence pedestrian detection, the jaywalker is also detected accurately. Figure 3(d) is the result of the jaywalker detection when there are several jaywalkers, every jaywalker is detected accurately, and the jaywalker's motion path is legible.

The method is programmed with VC, and it can meet the requirement of real-time detection in traffic system. The detection ratio is equal to the number of detected jaywalker divided by the real number of jaywalker in video. It is up to 90%.

There are two reasons result to fail. First, because the pedestrian's clothes are similar in color to road, the pedestrian segmentation is fragmented and the pedestrian recognition is unsuccessful. Second, the pedestrian tracking is unsuccessful when the pedestrian suddenly speed up from inactivity.

5. Conclusions

This paper presents a jaywalker detection method according to detect, recognize and track pedestrian and analyze the direction of pedestrian motion path. It is effective for monitoring video. For complex scene that the jaywalker is sheltered from the other pedestrian or vehicle, or speed up, the pedestrian tracking needs to improve in the future research.

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