Taxi Drivers' Smoking Behavior Detection in Traffic Monitoring Video

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Abstract— **Taxi is an indispensable part of the urban public transportation industry. However, the existence of illegal operating behaviors brings security risks to passengers and affects the city's civilization. The paper studies the detection methods of taxi drivers' smoking behavior during operation in the surveillance video environment. Firstly, the Vibe algorithm is used to detect the motion foreground of the video. Then the Haar-Adaboost algorithm is used to identify the taxi and extract the target detection area. The HSV color model is used to extract the color characteristics of the smoking smoke, and separate the target area from the moving objects which is similar to smoking smoke. Finally, combined changes in shape and movement characteristics of smoking smoke to further eliminate the interference objects, and the final detection results are obtained. The experimental results show that this algorithm has high real-time and accuracy, which is beneficial to off-site law enforcement in intelligent traffic management.**

I. Introduction

Transportation is an important service and strategic industry, and it takes up a basic and leading position in the development of national economy [1]. With a large population and a large demand for public transport in Beijing, taxis have gradually become a necessary means of transportation for people to take every day. However, some problems have become increasingly prominent, which has brought great troubles to transportation departments, such as the surge of people and traffic flow. It has increased violations of laws and regulations, traffic management difficulties and so on. With the continuous development of science and technology, intelligent video surveillance plays an increasingly important role in road traffic management. Using off-site law enforcement technology to solve the existing problems in the taxi industry is the current research hotspot [2]. It can not only improve the efficiency of road traffic management and achieve the safety management of the taxi industry, but also greatly alleviate the problem of insufficient personnel and human law enforcement in the process of traffic law enforcement.

Smoking of taxi drivers is an uncivilized behavior that affects the city's appearance. It not only pollutes the environment and brings troubles to passengers, but also causes civil disputes. Therefore, it is imperative to detect the smoking behavior of taxi drivers during their operation. At present, there are few studies on smoking detection. In reference [3], an algorithm combining Histogram of Oriented Gradient and Support Vector Machine (SVM) is proposed to detect cigarette smoke. In reference [4], a Convolution Neural Network (CNN) architecture is proposed to identify smoking activities with sensor-based daily equipment. In reference [5], an accelerator sensor is used to detect smoking behavior.

For the complex scene of taxi operation in this paper, the detection algorithms of the above simple smoking scene or these researches relying on sensor are not enough to provide help for this algorithm. Through research and development, it is found that the smoking behavior detection algorithm using smoking smoke is feasible. At present, fire smoke is the main object of smoke recognition in the field of video surveillance at home and abroad. I. Kopilovic proposed for the first time to extract moving objects by optical flow method. By counting the direction distribution of irregular movement when smoke diffuses, we can identify whether the moving objects are smoke [6]. Y. Yin distinguished real smoke from smoke-like objects by using the perimeter-area ratio of the moving area [7]. T. Chen used RGB color model to identify smoke based on the gray-white features of smoke early in the fire [8]. B. Ugur used the idea of wavelet transform to realize smoke detection [9].

In order to solve the problem that smoking behavior is difficult to detect in complex scenes and smoking smoke is difficult to identify in a sparse and small range. Firstly, Vibe algorithm is used to extract moving objects. Secondly, Haar-Adaboost algorithm, which has better real-time and robustness in classical algorithm, is selected to train taxi window specific area with color histogram matching algorithm. It can extract more accurate target detection area; finally, smoking behavior detection is realized by multi-feature fusion based on the color and dynamic features of smoking smoke. This research provides an automatic detection algorithm for urban traffic off-site law enforcement, and achieves the purpose of improving the management efficiency of relevant traffic departments.

II. Systematic Overview

A. Problem Description

Fig. 1 Detection scenario of this article.

In the taxi operation area of airports and railway stations, there are usually many taxis waiting for passengers. In the traffic monitoring video, many taxis ranging from single-row to four-row can be photographed in the monitoring screen. At the same time, there are some obstacles such as private cars, pedestrians, illumination, window glass which have similar color to smoke, reflections and other complex interference factors. Fig. 1 shows taxi operation pictures in a surveillance video. In order to help law enforcement officers regulate the working behavior of taxi drivers in the operation process, this paper proposes an algorithm to detect the smoking behavior of taxi drivers in traffic surveillance video. Traffic surveillance video scenes are complex and swarmed with numerous moving targets, drivers far away from the camera, and their actions blocked by the steering wheel. So the smoking behavior of drivers is difficult to distinguish in the video. However, it is found that smoking smoke would drift out of the main cab window, and the smoking behavior of taxi drivers could be detected by extracting the characteristics of smoking smoke.

B. *Algorithmic Flow*

The flow chart of smoking behavior detection algorithm for taxi drivers presented in this paper is shown in Fig. 2.

Firstly, the video data of traffic surveillance is acquired, and the taxi features in the video are extracted and recognized. Then the taxi driver is located in the main cab of the taxi. Finally the target detection area is located. On this basis, whether the taxi driver in the video has smoking behavior can identified according to the color and dynamic characteristics of smoke.

III. Locate Target Detection Area

A. *Taxi Recognition*

Based on the complex background of traffic surveillance video, the Vibe algorithm [10] is first used to extract the foreground of moving objects. The background model is created according to the neighborhood pixels, and the foreground is detected by comparing the background model with the current input pixel value. Secondly, by using the unique roof lamp design of taxis and the window area containing the cab, a window area detection method based on Haar-Adaboost algorithm is proposed to identify taxis in traffic video.

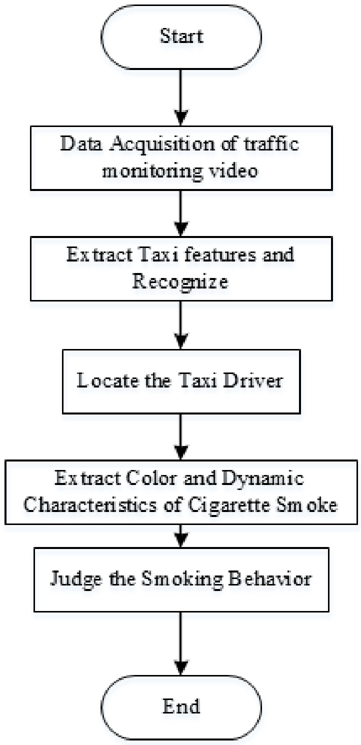

Fig. 2 Flow chart of smoking behavior detection.

Haar feature [11, 12] is an image feature descriptor for target detection or recognition. It can reflect the gray level change of an image and calculate the difference of the pixels by module. It is divided into four categories: edge feature, linear feature, center feature and diagonal feature. A feature template is composed of black rectangular box. And white rectangular box, the template's eigenvalues are represented by the difference between the sum of black rectangular pixels and the sum of white rectangular pixels. The Haar feature templates is shown in Fig. 3.

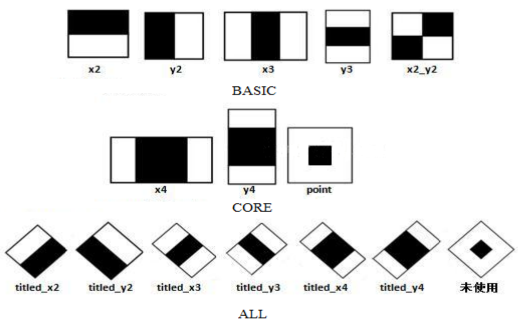

Fig. 3 Harr feature templates.

The Adaboost algorithm is a supervised learning algorithm. The core is to promote weak learning to strong learning. Through the repeated learning, multiple weak classifiers are obtained, and the error rate of the hypothesis is adaptively adjusted according to the learning result of the weak classifier to form a strong classifier. When training the weight of the weak classifier data, reduce the weight of the sample that was correctly classified in the previous round, and improve the weight of the sample that is misclassified to improve the classification accuracy. When cascading multiple weak classifiers into strong classifiers, the weighted majority voting method is used to increase the weights of weak classifiers with small classification error rate and reduce the weights of weak classifiers with large classification error rate. The Adaboost algorithm has high accuracy and considers the weights of each classifier. The training model of the weak classifier is

$$\varepsilon_m = \sum_{n=1}^{N} \omega_n^{(m)} I(y_m(x_n) \neq t_n) \quad (1)$$

Among them: ε_m is the weight error after optimization, $y_m(x_n)$ is the prediction result of weak classifier, t_n is the real value, I is the optimization function of weight coefficient, $\omega_n^{(m)}$ is the weight value of current weak classifier.

Strong classifier model is

$$Y_M(x) = sign(\sum_{m=1}^{M} \alpha_m y_m(x)) \quad (2)$$

Among them: M is the number of weak classifiers, α_m is the weight coefficient of each weak classifier, $y_m(x)$ is the calculation result of each weak classifier, and $Y_M(x)$ is the final classification result.

The training set adopted in this paper contains 2767 positive samples of taxi area and 7219 negative samples of environment. The positive samples are normalized to 28*20 and the negative samples are normalized to 480*360. Some samples are shown in Fig. 4.

B. Extract Target Detection Area

Fig. 5 Target detection area.

The taxi driver has a smoking behavior during the operation, that is, there is smoking behavior in the main cab, and the target detection area in the traffic monitoring video is the right half of the taxi window. When the driver smokes in this scene, it can be observed that the smoking smoke is scattered from the cab to the window. Therefore, when designing an algorithm for smoking violations based on smoking smoke, the main target detection area is the smoke dispersion area outside the cab window, as shown in Fig. 5.

The length L and width H of car rental windows are calculated. The red box in the picture is smoke detection area. According to experiments and a large number of video surveillance, the length and width of target detection area are L_0 and H_0.

$$L_0 = \frac{1}{3} L \quad (3)$$

$$H_0 = \frac{1}{3} H \quad (4)$$

IV. Extraction of Smoke Characteristics

A. Color Characteristics of Smoke

Smoking smoke is usually translucent gray. The values of r, g and B in RGB color model are similar, and the transparency

Fig. 4 Taxi's training samples.

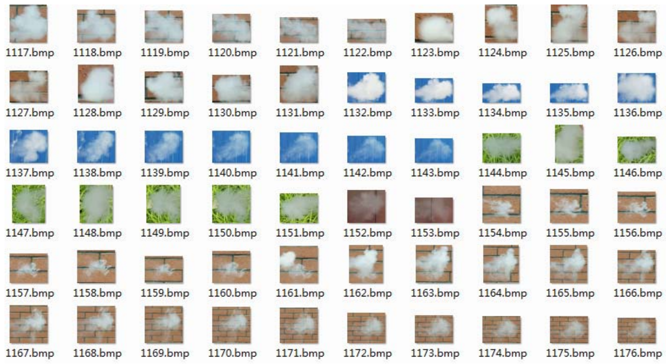

Fig. 6 Smoke sample sets.

of smoke cannot be expressed. HSV color model [13] completely separates hue, value and saturation, which is more in line with the visual characteristics of human eyes, and can more accurately extract the color features of smoke.

600 true color smoke images (as shown in Fig. 6) were selected to create a smoke data set. And the smoke characteristics of HSV color model were extracted by Histogram Statistical algorithm.

It is found that the components of h, s and v are all centrally distributed in a small range. The following conditions can be used as the decisive conditions for smoking smoke recognition:

$$\begin{cases} 0.22 < h < 0.45 \\ 0.10 < s < 0.32 \\ 0.20 < v < 0.65 \end{cases} \quad (5)$$

B. Dynamic Characteristics of Smoke

After smoking smoke is produced, its movement and diffusion characteristics are as follows: smoke drifts outward from the window, and its trajectory moves upward from the window to the right; smoke has complex contour shape, which will gradually expand and change with its diffusion.

There are many algorithms to extract smoke using dynamic characteristics. To meet the real-time detection requirement of the system, feature extraction is usually based on the principles of low computational complexity, fast processing speed, easy extraction and good recognition effect of smoke.

(1) Area ratio of minimum bounding rectangle of the smoke contour to smoke contour

Smoking smoke can maintain its contour shape well in the diffusion process, which is quite different from other moving objects in this scene. The contour area ratio of minimum bounding rectangle of the smoke contour to smoke contour is selected to express its characteristics.

$$r = \frac{S_1}{S_2} \quad (6)$$

Among them, S_1 is the area of minimum bounding rectangle of the smoke contour and S_2 is the area of smoke contour.

Comparing the area ratios between smoke and non-smoke area, we found that the area ratio of smoke contour in its minimum bounding rectangle varies slightly with its diffusion, and it varies within a certain range with the movement of video frames.

$$A_1 < A_{agr} < A_2 \quad (7)$$

Among them, A_{agr} is the area ratio of the minimum bounding rectangle of the smoke contour to smoke contour, A_1 and A_2 are the upper and lower thresholds of the area ratio.

(2) Perimeter ratio of smoke contour convex hull to smoke contour

The shape of smoke is extremely irregular, and its contour is tortuous and complex. Compared with most rigid objects, the complexity of smoke contour is an important feature. The ratio of minimum bounding rectangle of the smoke contour to smoke contour is chosen to represent the special shape and irregularity of smoke:

$$r = \frac{C_1}{C_2} \quad (8)$$

where C_1 is perimeter of the smoke contour convex hull, and C_2 is perimeter of the smoke contour.

Compare the perimeter ratios between smoke and non-smoke. It is shown that the perimeter ratio of smoke is obviously larger than that of non-smoke.

(3) Moving direction of centroid of smoke contour

When cigarette smoke drifts outward from the cab window, its trajectory moves upward to the right, which can be used as a smoke feature to distinguish cigarette smoke from other moving targets. Firstly, the moving foreground of the target area is detected and processed morphologically, then the smoke contour is extracted and its centroid is calculated. Finally, the centroid coordinates of the same contour are compared between frames to determine its trajectory:

$$\begin{cases} mc[i+1].x > mc[i].x \\ mc[i+1].y < mc[i].y \end{cases} \quad (9)$$

where $mc[i].x$ and $mc[i].y$ are the horizontal and vertical coordinates of contour centroid in current frame, $mc[i+1].x$ and $mc[i+1].y$ are the horizontal and vertical coordinates of the corresponding contour centroid in next frame.

V. Experimental Results

In order to evaluate the applicability of this algorithm, the sample sets and video sets used in training and testing are all from the real traffic surveillance video of Beijing Traffic Law Enforcement Team, the number of videos is 132.

The results of the motion foreground detected by Vibe algorithm are shown in Fig. 7 (a). The detection area for locating taxi drivers' smoke is shown in Fig. 7 (b). This process eliminates interference such as window and the sides of cars reflection. Finally, smoking behavior is identified based on the color and dynamic characteristics of cigarette smoke. The motion foreground of taxi drivers smoking behavior are shown in Fig. 7 (c). Traffic monitoring videos were tested and the experimental results are showed in Fig. 7 (d) (e).

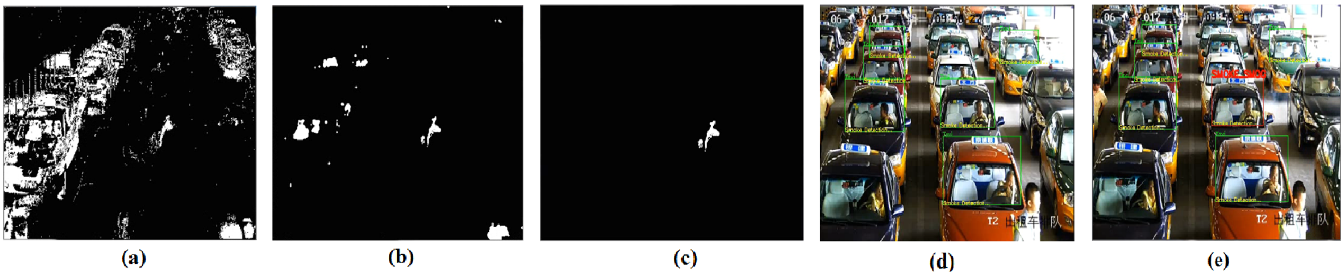

Fig. 7 (a): Motion foreground detected by Vibe algorithm. (b): Target detected by Vibe algorithm and cigarette-smoke features. (c): Motion target after Vibe algorithm, smoke features detection and target area extraction. (d): No smoking behavior experimental result. (e): Smoking behaviors were detected.

Table I and Fig .8 shows the comparison results between different algorithms. In reference [13], firstly, background modeling and motion foreground detection are carried out by combining Mixture Gauss Model and frame difference method. Secondly, based on the color characteristics of smoke, HSV color model is used to recognize smoke. This algorithm has a faster processing speed, but the detection effect is poor. It is shown four false detection in Fig. 8 (a). Because the experimental scenes in traffic monitoring video are more complex. There are a large number of moving objects with similar color to smoke, so the accuracy of smoking behavior detection using only the color characteristics of smoke is not high. Literature [15] firstly uses Vibe algorithm to extract the moving foreground, secondly eliminates smoke-like interference by calculating the color probability of four RGBA channels, and finally determines the final detection result by the shape characteristics of smoke. The real-time performance of the algorithm is better and the recognition rate is higher than that of the algorithm in [13]. However, there are still misdetection can be seen in Fig. 8 (b) and the detection effect of the algorithm is not very ideal. Because the detection scenario of the algorithm is more suitable for visible smoke. Reference [16] uses Mixture Gauss Model to extract moving targets, combines HSV and RGB model to extract suspected smoke areas, and finally identifies smoke through the dynamic characteristics of smoke(Mean and variance of motion speed, direction of motion, area growth rate). As can be seen from Fig. 8 (c), the detection effect of the algorithm is better, but the real-time performance is not high. Experiments show that the real-time performance of the algorithm is worse than that of Vibe algorithm. By analyzing the practical application scenarios, the algorithm proposed in this paper is more suitable for the taxi operation scenarios. It has a good detection result and meets the real-time requirements. The recall rate (RR) is 68.73%, and the false positive rate (FPR) is 18.84%.

TABLE. I
COMPARISONS OF TEST PERFORMANCE OF DIFFERENCE ALGORITHMS.

Algorithm	Time[ms]	RR	FPR
Pan's method[13]	28.15	19.54%	84.25%
Wang's method[15]	29.34	53.32%	24.28%
Tang's method[16]	68.59	61.41%	20.87%
Proposed	32.56	68.73%	18.84%

$$RR = \frac{True\ positives}{True\ positives + False\ negatives} \tag{10}$$

$$FPR = \frac{False\ positives}{False\ positives + True\ negatives} \tag{11}$$

VI. CONCLUSIONS

The purpose of this paper is to solve the problems in the process of off-site traffic law enforcement and the development of intelligent traffic. This paper proposes an automatic monitoring algorithm for the illegal behavior of taxi drivers who smoke during operation. Firstly, based on the unique sign of the taxi roof lamp and Haar-Adaboost algorithm, the taxi window is located in target area, which solves the problem of vehicle occlusion in the complex scene, and can more accurately locate the target area where smoking

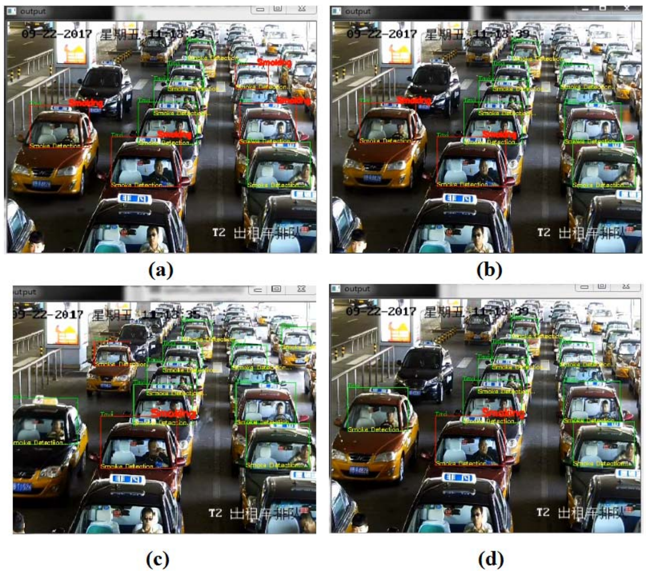

Fig. 8 Experimental results of different algorithms. (a): Pan's method. (b): Wang's method. (c): Tang's method. (d): Proposed method.

occurs. Secondly, the HSV color model is used to extract the color features of cigarette smoke and obtain the suspected smoke area, which eliminates the motion foreground that does not satisfy the smoke color model. Then, combining the three dynamic characteristics of cigarette smoke to further identify the smoke, exclude the interference objects, screen out cigarette smoke. Finally the purpose of smoking behavior detection was achieved. The experimental results show that the algorithm proposed in this paper is an effective and feasible automatic monitoring algorithm for taxi drivers' smoking behavior in the operation process. The recall ratio reaches 68.73%, which provides some help for the actual traffic law enforcement. For the false detection and missed detection in this paper, further optimization and upgrading will be carried out in follow-up works.

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