Driver's Face Detection Using Space-time Restrained Adaboost Method

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Abstract

Face detection is the first step of vision-based driver fatigue detection method. Traditional face detection methods have problems of high false-detection rates and long detection times. A space-time restrained Adaboost method is presented in this paper that resolves these problems. Firstly, the possible position of a driver's face in a video frame is measured relative to the previous frame. Secondly, a space-time restriction strategy is designed to restrain the detection window and scale of the Adaboost method to reduce time consumption and false-detection of face detection. Finally, a face knowledge restriction strategy is designed to confirm that the faces detected by this Adaboost method. Experiments compare the methods and confirm that a driver's face can be detected rapidly and precisely.

Keywords: Adaboost, face detection, facial expression recognition, fatigue detection

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1. Introduction

About 57% of fatal automobile accidents in the transportation industry are due to driver fatigue from sleep deprivation or sleep disorders. A solution, then, has great socio-economic value [1]. It is possible to prevent accidents by developing systems for monitoring driver fatigue and alerting a drowsy driver that is not paying adequate attention to the road. Many countries and research groups all over the world have begun to pay attention to the possibility of providing cars with sensors that monitor the steering wheel, brakes, accelerator, lane keeping, etc. [2]. Among these studies, vision-based facial expression recognition methods are effective and convenient ways to detect whether the driver is inattentive and then generate warning alarm to alert the driver [3][4][5][6]. Vision-based recognition of facial expression consists of three tasks: face detection, facial expression information extraction, and expression classification [7]. Face detection is the first step for this process, i.e., to locate the driver's face.

It is challenging to develop a robust face detection method because of face diversity (e.g., the variability in size, location, pose, orientation, and expression) and also the changes in environmental conditions (e.g., illumination, exposure, and occlusion) [8]. Yet many successful methods have been developed. Color spaces, such as RGB, HSV and YCrCb, have been utilized to label pixels as human skin [9][10][11]. These methods are very simple and fast but not sufficient to detect faces with complicated backgrounds. Some robust methods such as neural networks, Support Vector Machines (SVMs), Hidden Markov Model (HMM), and Active Shape Model (ASM) can detect faces with complicated backgrounds [12][14][15]. But these methods are complex and computationally expensive. Viola and Jones designed a face detection framework based on Adaboost learning, which can detect faces in an image rapidly while achieving high detection rates by introducing rectangle features, integral images and cascade structures of classifiers [16]. However, this method cannot satisfy the need for real-time detection in embedded platforms such as TMS320DM642 used by fatigue detection systems. Furthermore, the false detection rate is still high in applying this method for using in fatigue detection systems.

This paper presents a space-time restrained Adaboost method based on the requirements of fatigue detection systems. Firstly, the possible position of a driver's face in the current video frame is measured relative to the previous frame. Secondly, a space-time restriction strategy is designed to restrain the detection window and scale of the Adaboost method, in a way to reduce time consumption and false-detection of face detection. Finally, a face knowledge restriction strategy is designed to confirm the faces detected by Adaboost.

The rest of this paper is organized as follows: Section 2 describes the Adaboost method. In Section 3, the proposed detection method is described. Results of face detection tests are presented in Section 4, together with a comparison between the proposed method and Adaboost method. Conclusions are summarized in Section 5.

2. Face Detection Based On The Adaboost Method

Face detection based on the Adaboost method has three key components: (1) rapid features extraction using integral images; (2) an efficient classifier that selects a small number of important features from a very large data set using an Adaboost learning algorithm [17]; (3) combining more complex classifiers in a cascade structure which focuses on promising face-like regions while rapidly discarding background regions. The flowchart of a face detection method based on Adaboost is shown in **Fig.1**.

Step 1: Compute Harr-like features of input image, using integral images for rapid calculations;

Step 2: Collect multi-scales images from the input image to make the method adapt different face scales;

Step 3: Collect an unprocessed image from the multi-scales images and go to next step. If there is no image that has been processed, output the face detection results;

Step 4: Set the image for the cascade classifier that was trained using the Adaboost algorithm;

Step 5: Collect multi-window sub-images from the image to detect faces in different positions;

Step 6: Collect an unprocessed sub-image from multi-window sub-images and go to next step. If no sub-image has been processed, go to Step 3;

Step 7: Run the cascade classifier to recognize the sub-image as a face or non-face, and go to Step 6 after recording the face detection results.

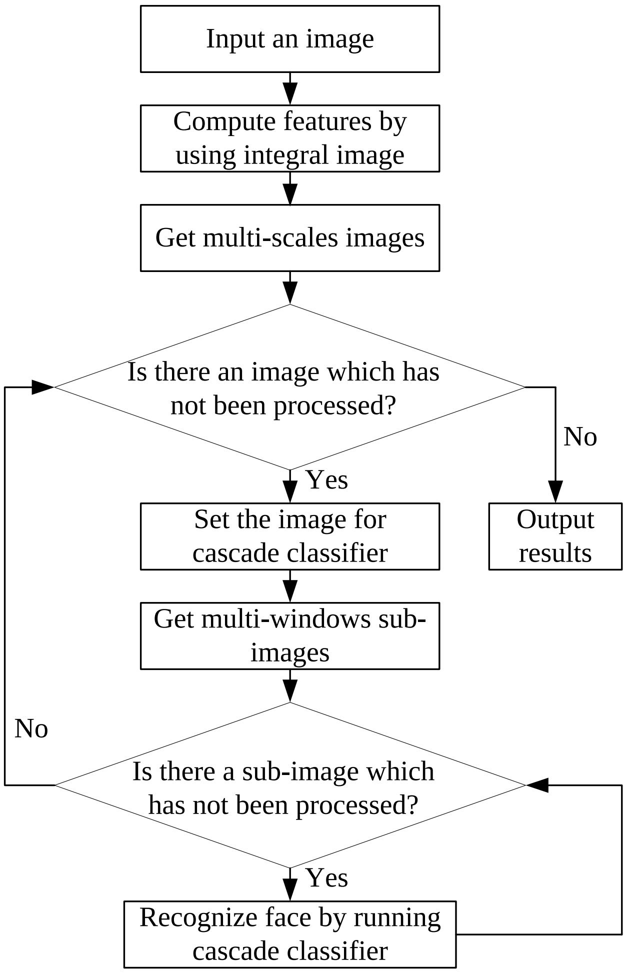

Fig. 1. Flowchart of Adaboost face detection method

3. The Proposed Method

There are two prior-terms for faces in a driver fatigue detection system: (i) the position of the face changes little during driving process; (ii) there is not more than one face in the captured frame.

Based on these prior-terms, this paper presents a space-time restrained Adaboost method. The flowchart is shown in **Fig.2**. Compared with the traditional Adaboost method in **Fig.1**, the new method has three restriction strategies as follows:

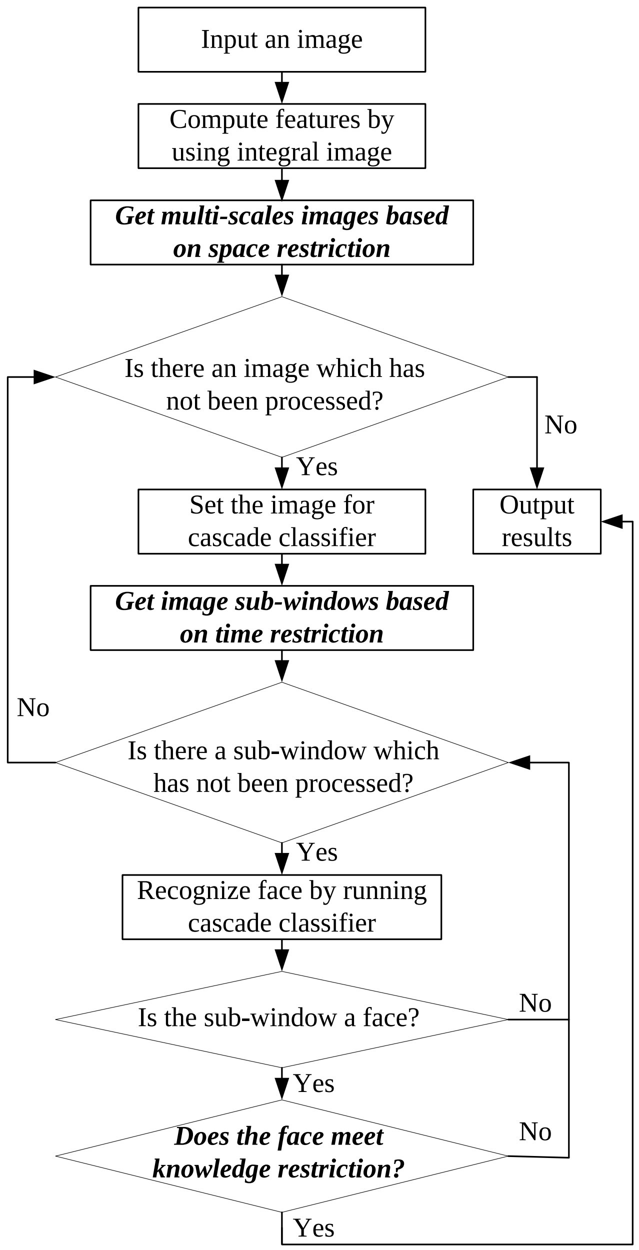

Fig. 2. Flowchart of face detection method based on space-time restrained Adaboost

(1) Time restriction strategy. A frame differential method is executed to detect the moving targets; the possible position of a face in the current frame is calculated according to the previous frame based on the prior-term (i); finally, the detection window of the Adaboost method is restrained according to the possible position of the face to avoid computational time consumption and false face detection in non-face windows.

(2) Space restriction strategy. The detection scale of Adaboost method is restrained according to the size of the face detected in the previous frame and prior-term (i), in this way to avoid computational time consumption and false face detection in non-face scales.

(3) Knowledge restriction strategy. The possible sub-window face detected by the Adaboost method is confirmed according to face knowledge [18], to reduce false detections. If the sub-window meets knowledge restrictions, the process of face detection can be ended immediately according to prior-term (ii), to reduce computational time consumption. The detailed process of the space-time restriction strategy is described as follows:

Step 1: Finding the possible face position. .

Let $P_0(P_{0x}, P_{0y})$ be the center position of the detected face with size of $f_{0w}\times f_{0h}$ in the previous frame. If there is no face in the previous frame, $P_{0x}=P_{0y}=-1$, $f_{0w}=f_{0h}=0$. The possible position, $P(P_x, P_y)$ of the face in the current frame can be calculated as follows:

Step 1-1: Use three frame differential method [19] to detect moving targets in the current frame, and record the size and position of all detected targets.

Step 1-2: Find the largest target with area S and center position P_1. This target has a higher possibility to be a face than others because the real face occupies a larger area in video frame capture.

Step 1-3: Because the driver's face does not move or moves just a little sometimes, the largest target is not a possible face when S<T, where T is a threshold. In this situation, $P=P_0$; otherwise, $P=P_1$. In this paper, T is set to 6400 in the VGA experimental images.

If $P_x=P_y=-1$, or $f_{0w}=f_{0h}=0$, we do not restrain the detection window and scale of the Adaboost method. Go to Step 4; otherwise, go to Step 2.

Step 2: Restraining the detection scale of the Adaboost method.

The size of faces between two contiguous frames change little according to prior-term (i) so the restriction strategy can be described by the following formulas:

$$\begin{cases} MaxW = k_1 \times f_{0w}, MaxH = k_1 \times f_{0h} \\ MinW = k_2 \times f_{0w}, MinH = k_2 \times f_{0h} \end{cases}$$

where ($MaxW$, $MaxH$) is the maximum scale of the Adaboost method, ($MinW$, $MinH$) is the minimum scale of the Adaboost method, k_1 and k_2 are coefficients. In this paper, k_1 and k_2 are set to 1.5 and 0.5 respectively according to experiments.

Step 3: Restraining the detection window of the Adaboost method.

The restriction strategy can be described by the following formulas:

$$\begin{cases} (P_x - k_3 \times f_{0w}) < x < (P_x + k_3 \times f_{0w}) \\ (P_y - k_4 \times f_{0h}) < y < (P_y + k_4 \times f_{0h}) \end{cases}$$

where (x, y) is any pixel in the detection window of the Adaboost method, k_3 and k_4 are coefficients. In this paper, k_3 and k_4 are all set to 1.0 according to experiments.

Step 4: Updating parameters.

If a real face with the size of $f_w \times f_h$ and center position of $P(P_x, P_y)$ is detected in the current frame, parameters are updated as follows: $P_0=P$, $f_{0w}=f_w$, $f_{0h}=f_h$.

4. Experiment and Analysis

In order to evaluate the performance of the proposed method, a driver video clip was tested using Viola's Adaboost method [16], Guo's Adaboost method [20] and compared with the proposed method. The test video is with a VGA image output of 25 frames per second (fps). The results and performance analysis of face detection with the different methods are shown in **Fig.3** and Table 1 respectively.

Fig.3 (a1)-(a6) shows six images from the test video with different frame number. In **Fig.3 (b1)-(b6), (c1)-(c6)** and **(d1)-(d6)**, the white rectangle represents the face detection region. It is obviously that **Fig.3 (b1)-(b6), (c1)-(c6)** has more false detection faces than **Fig.3 (d1)-(d6)**. The reasons can be seen in Table 1 where the detection window and scale of Viola's Adaboost method [16] and Guo's Adaboost method [20] are much larger than that of the proposed method. The proposed method avoids computational time consumption and false face detection in non-face windows and scales. Furthermore, knowledge restriction strategy is executed to confirm the detected faces and end the process of face detection once a real face is detected.

(a1)

(a2)

(a3)

(a4)

(a5)

(a6)

(b1)

(b2)

(b3)

(b4)

(b5)

(b6)

(c1)

(c2)

(c3)

(c4)

(c5)

(c6)

(d1)

(d2)

(d3)

(d4)

(d5)

(d6)

Fig. 3. Results of face detection. (a1) - (a6): images from a driver video; (b1) - (b6): results of face detection using Viola's Adaboost method; (c1) - (c6): results of face detection using Guo's Adaboost method; (d1) - (d6): results of face detection using the proposed method.

Table 1. Performance analysis among different face detection methods (time units of TMS320DM642 platform in milliseconds)

Method	Frame Number	Detection window		Detection scale		The number of false-detection faces	Time consumption
		Top-left point	Bottom-right point	Minimal scale	Maximal scale		
Viola's method [16]	50	(0,0)	(639, 479)	(20,20)	(639,479)	5	2432
	210					7	2510
	280					11	2706
	400					5	2600
	450					9	2599
	530					4	2400
Guo's method [20]	50	(0,0)	(639, 479)	(20,20)	(639,479)	1	1605
	210					1	1352
	280					2	1790
	400					1	1471
	450					2	1699
	530					1	1442
The proposed method	50	(209,3)	(521,315)	(80,80)	(240,240)	0	33
	210	(254,16)	(588,350)	(101,101)	(303,303)	0	47
	280	(282,2)	(590,310)	(91,91)	(273,273)	0	35
	400	(252,22)	(606,376)	(116,116)	(348,348)	0	51
	450	(248,11)	(586,349)	(89,89)	(267,267)	0	40
	530	(256,9)	(589,342)	(87,87)	(261,261)	0	38

5. Conclusions

This paper presents a space-time restrained Adaboost method which can be used to detect faces rapidly and precisely in a driver fatigue detection system. The advantages of the proposed method are that: (1) computational time consumption and false face detection in non-face windows and scales can be avoided according to a space-time restriction strategy on the Adaboost method; (2) the detected faces can be confirmed again according to a knowledge restriction strategy; (3) the process of face detection can be ended once a real face is detected. Future work will extract fatigue features from a driver's face.

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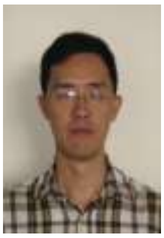

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