DISCRIMINATION OF A DRIVER'S STATE USING FACE TRACKING

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Abstract

This paper presents a system of discriminating drivers' posture using face tracking for driver support. A camera is arranged near a rear-view mirror of a car, since the setting does not conflict with the law and is easy to implement. A driver's facial region is first detected by template matching. The region is tracked using color information. CAM-shift tracking or Mean-shift tracking is used for the face tracking. A driver's posture is discriminated using the location of the face in images. The threshold for discriminating a driver's state driver is established empirically. The effectiveness of the system is evaluated by experiments in which a driver wears glasses, a cap, or a mask.

1 Introduction

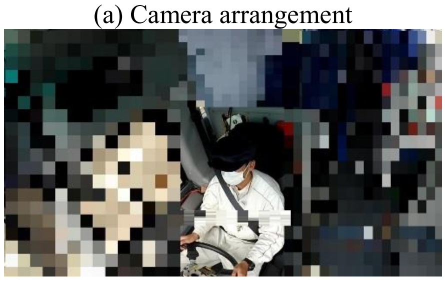
In the past few years, there have been many attempts to detect drivers' states [1]. Eskandarian *et al*. [2] found that some actions (eye-blinking, touching the body and many others) were correlated with fatigue. In particular, PERCLOS (the percentage of time in which the eyelids are closed) is one of the most famous measures for detecting sleepiness. In many studies that seek to detect drivers' drowsiness, methods that measure the time driver's eyes closed are used. Lang and Qi [3] proposed an algorithm for detecting driver fatigue based on skin color segment in color images using PERCLOS and AECS (average eye closure speed). Chang and Chen [4] proposed a driver-monitoring system that would measure a driver's face and eyes using image-processing techniques to detect them in a frame using a regular camera. Friedrichs and Yang [5] showed 18 features for drowsiness detection from the eye signals returned by the camera system. In addition to these, Toyota developed their Driver Monitoring System which tracks the movement of the driver's head using a camera arranged on top of the steering column cover using near-IR technology. When the system detects that the driver is looking away from the road and a collision menace at the same time, it will sound an alert and apply the brakes [6].

In many driver-supporting systems, the application's targets are often new cars. However, there is difficulty in making the systems an option for used cars, due to the limitations of the law, cost, and sensor arrangements.

In our system, a camera is arranged near a rear-view mirror of a car, since the arrangement does not conflict with the laws and is easy to implement. It is difficult to detect the driver's eyes when the driver is wearing a cap and the camera is used as shown in Fig. 1. This paper supposes the system to discriminate driver's state using face tracking. The purpose of our system is to detect the driver's state based on movement of the driver's face.

The rest of the paper is organized as follows. In section 2, we explain the algorithm of our system. In section 3, we explain the experiments designed to test our system of discriminating the driver's state. Finally, in section 4, we draw conclusions and discuss our future work.

(a) Camera arrangement



(b) Acquired image

Fig. 1 Conceptual diagram of camera arrangement

2 A system for discriminating a driver's state

Our proposed system uses a camera arranged near a rear-view mirror of a car, as shown in Fig. 1. The algorithm for discriminating driver's state is shown in Fig. 2. First, the driver's facial region is detected with template matching. The region is tracked using color information. The CAM-shift [7] method or the Mean-shift [8] method is used for face tracking. Finally the driver's state is discriminated by the location of the face in images. The fixed region used for discriminations is established empirically. When tracking is unsuccessful, the facial region is re-detected with template matching.

2.1 Driver detection

It is assumed that the driver will have correct posture immediately upon sitting. The region of driver detection shown in Fig. 3 is established empirically. The driver's face is detected using template matching in the region using normalized cross-correlation. The template images are images of the driver's face. Fig. 4 is an example of a template image.

2.2 Face tracking

After driver detection or re-detection, our system obtains a histogram of the hue information of the detected facial region in images. In each frame, our system handle saturation and luminance threshold and track the face using the CAM-Shift or the Mean-Shift method. The algorithm of color tracking is shown in Fig. 5. The Mean-shift algorithm is a non-parametric technique that climbs the gradient of a probability distribution to find peak. CAM-shift is based on Mean-shift algorithm that find the nearest dominant mode from a given probability destiny image. First, calculation region of the probability distribution is set. Second, the initial location of the search widow is chosen. Third, center of color probability distribution is calculated. Fourth, the zeroth moment and mean location are stored. Finally, the search window is updated for the next frame [7]. The great difference of two methods is changing search window's size and orientation in updating to the next frame. In this paper, the two methods are used independently. Tracking results are shown in Figs. 6 and 7. The red ellipse is tracking region in Fig. 6. The green square is tracking region too, in Fig. 7. Frame rate is shown in upper left.

2.3 Discriminating posture

After face tracking, the driver's state is discriminated by whether the driver's posture is represented by a position of the tracker. In our system, the fixed region is set as shown in Fig. 8 for detecting driver's posture. When the location of driver's face is outside the region for discrimination, the driver’s state is considered to be as shown in Fig. 9.

2.4 Re-Detection for tracking failure

It is assumed that tracking results in failure the cases (a) or (b)

(a) the distance of the target between adjacent frames is greater than threshold.

(b) the search window's size is greater or less than the thresholds.

When tracking is unsuccessful, the facial region is re-detected using template matching, and the histogram is updated.

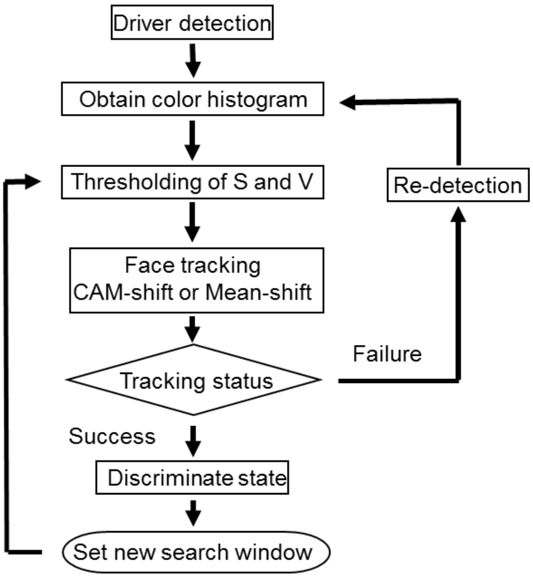


Fig. 2 Our system's flow


Fig. 3 Input image


Fig. 4 Example of a template image

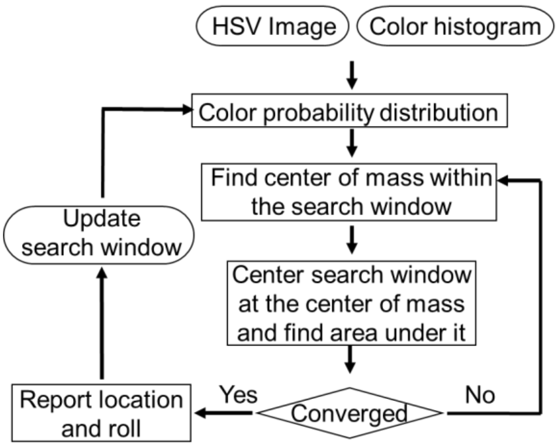
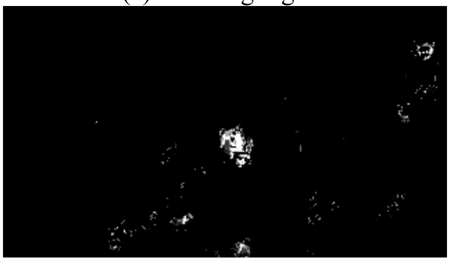


Fig. 5 Diagram of color object tracking [7]

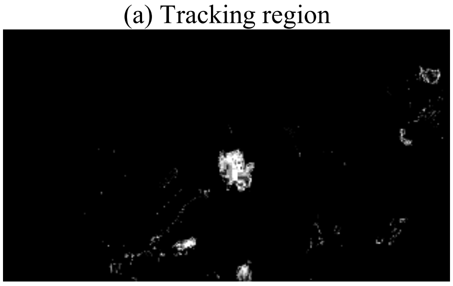
(a) Tracking region



(b) Extracted target color regions

Fig. 6 An example of CAM-shift tracking

(a) Tracking region



(b) Extracted target color regions

Fig. 7 An example of Mean-shift tracking

Fig. 8 The fixed region of discrimination

Fig. 9 Discrimination of posture

3 Evaluation Experiments

We tested two methods (using the CAM-shift method and the Mean-shift method) in test course. A motor coach was used for the experiment. A color camera (GoPro HERO3+, 60[fps]) was arranged near a room mirror to take videos, as shown in Fig. 1. The driver was wearing the items shown in Table 1. We classified 3 postures, as shown in Fig. 12. The driver reproduced these postures. Videos were taken in the morning and in the afternoon, were used for evaluation. The subject is one driver. The weather was partly cloudy.

For our evaluation, we used 900 frames with normal posture and 600 frames with classified 3 postures. Two hundred frames were used in each of 3 postures. We verified the two methods for each wearing pattern. Equations (1) and (2) are used for verification. The results of the experiments are shown in Tables 2 ~ 5.

$$S_t = \frac{A - B}{A} \quad (1)$$

$$S_d = \frac{A - B - C}{A} \quad (2)$$

S_t is the success rate of tracking. S_d is the success rate of discrimination. A is the total number of frames. B is the number of frames in which mistracking occurred. C is the number of frames in which discrimination failed, although the tracking was successful.

With the CAM-shift method, S_t was more than 95% when the driver was wearing glasses, a cap or nothing as shown in Tables 2 and 3. However, it failed to track when the driver was wearing multiple items. Discrimination also failed due to tracking failure.

With the Mean-shift method, S_t was more than 85% when the driver was wearing glasses, a cap, or nothing, as shown in Tables 4 and 5. It was also able to track more successfully than the CAM-shift method in patterns G and H. However, in some cases, driver determination failed.

With the CAM-shift method in patterns G and H, tracking failed due to the removal of a mask from the tracking region. This occurred due to the saturation threshold. We are considering using other histograms (for example, combining H and S). However, the solution cannot be satisfactory, due to the similarity between a cap and a cloth. The region of a clothing item is included in tracking region as shown in Fig. 17. The reason for the higher success rate in tracking with the Mean-shift method is thought to be related to the fact that the search window's size does not change. The reason for the failure to discriminate the driver’s state is likely that the driver's face incline was comparable to the template image. We must introduce a robust detection method if the driver's face is inclined.

Table 1. Pattern of items the drive wrote

Pattern	Items the driver wore
A	Nothing
B	Glasses
C	A cap
D	A mask
E	Glasses and a cap
F	Glasses and a mask
G	A cap and a mask
H	Glasses and a cap and a mask

Table 2. The result of tracking and discrimination when using the CAM-shift method for normal posture

Pattern	S_t [%]	S_d [%]
A	99	99
B	99	99
C	95	94
D	99	98
E	86	86
F	85	85
G	59	59
H	34	34

Table 3. The result of tracking and discrimination when using the CAM-shift method for classified 3 postures

Pattern	S_t [%]	S_d [%]
A	99	92
B	99	93
C	99	94
D	70	68
E	98	89
F	70	66
G	51	44
H	26	22

Table 4. The result of tracking and discrimination when using the Mean-shift method for normal posture

Pattern	S_t [%]	S_d [%]
A	99	99
B	99	99
C	87	86
D	92	88
E	99	99
F	99	93
G	78	77
H	75	74

Table 5. The result of tracking and discrimination when using the Mean-shift method for classified 3 postures

Pattern	S_t [%]	S_d [%]
A	89	68
B	85	77
C	99	87
D	97	93
E	84	71
F	87	84
G	80	69
H	80	60

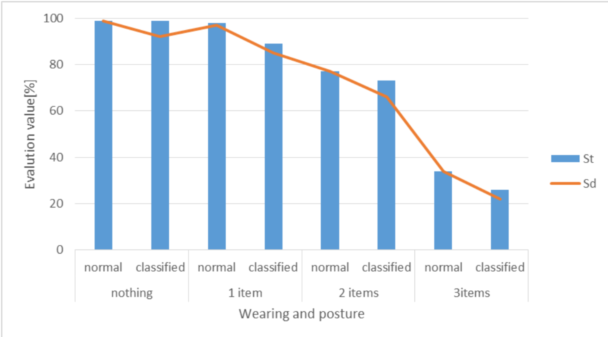


Fig. 10 Result of experiments using the CAM-shift method

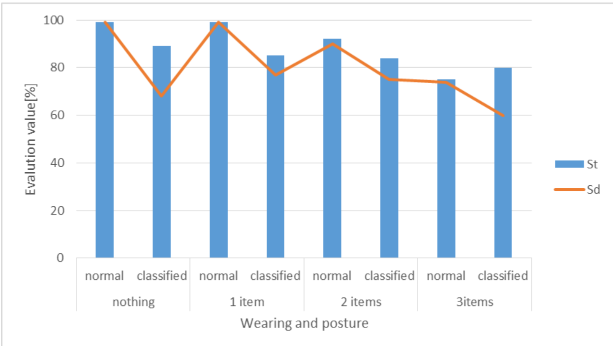
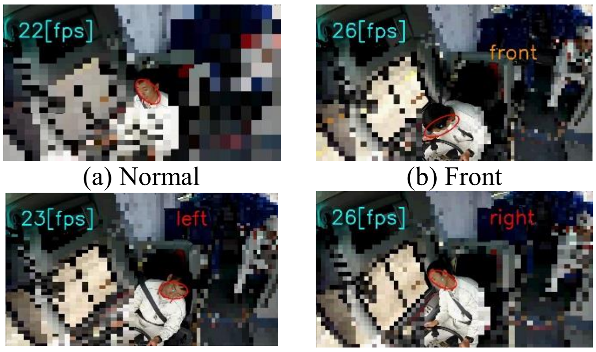


Fig. 11 Result of experiments using the Mean-shift method

(a) Front

(a) Left (b) Right

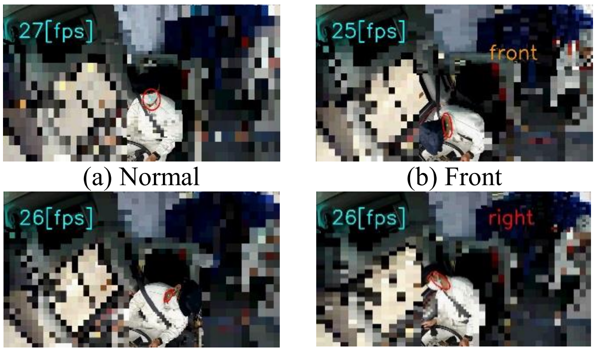
Fig. 12 Classified 3 postures for discrimination the driver's state



(a) Normal (b) Front

(c) Left (d) Right

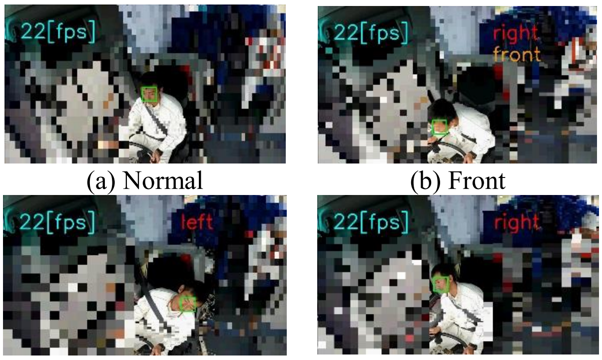
Fig. 13 Result of experiments using the CAM-shift method in pattern A



(a) Normal (b) Front

(c) Left (all frames failed) (d) Right

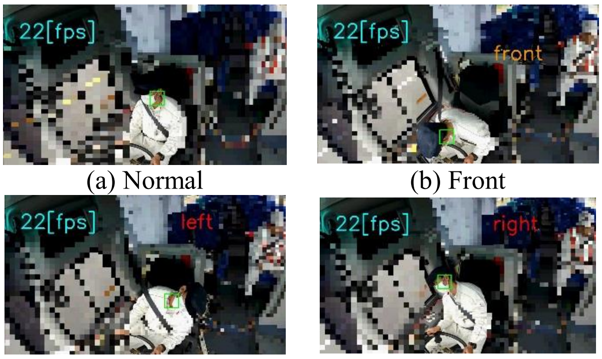
Fig. 14 Result of experiments using the CAM-shift method in pattern H



(a) Normal (b) Front

(c) Left (d) Right

Fig. 15 Result of experiments using the Mean-shift method in pattern A



(a) Normal (b) Front

(c) Left (d) Right

Fig. 16 Result of experiments using the Mean-shift in pattern H

(a) 114th (b) 684th

Fig. 17 Using other histograms (H and S)

4 Conclusions and Future works

This paper presents a system for discrimination a driver's posture using face tracking for driver monitoring. The effectiveness of the system has been evaluated by experiments for a driver wearing glasses, a cap, or a mask. However, tracking failed when the driver was wearing multiple items.

We will introduce the methods that is robust to illumination variation. We also need to build a system that is robust when the driver is wearing various items.

References

[1] Dong, Y. *et al.*, “Driver Inattention Monitoring System for Intelligent Vehicles: A Review,” IEEE Transactions on Intelligent Transportation Systems, Vol. 12, No. 2, June 2011, pp. 596–614.

[2] Eskandarian, A. *et al.*, “Advanced Driver Fatigue Research,” Federal Motor Carrier Safety Administration, April 2007.

[3] Lang, L. and Qi, H., “The Study of Driver Fatigue Monitor Algorithm Combined PERCLOS and AECS,” International Conference on Computer Science and Software Engineering, 2008, pp. 349–352.

[4] Chang, T.H. and Chen, Y.R., Driver Fatigue Surveillance via Eye Detection,” IEEE International Conference on Intelligent Transportation Systems (ITSC), October 2014, pp. 366–371.

[5] Friedrichs, F. and Yang, B. “Camera-based Drowsiness Reference for Driver State Classification under Real Driving Conditions,” IEEE Intelligent Vehicles Symposium, June 2010, pp. 101–106.

[6] http://www.testdriven.co.uk/lexus-ls-600h/.

[7] Bradski, G.R. et al., “Computer Vision Face Tracking For Use in a Perceptual User Interface,” Intel Technology Journal, 1998, pp. 1–15.

[8] Cheng, Y., “Mean Shift, Mode Seeking, and Clustering,” IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 17, No. 8, 1995, pp. 790–799.