Robust Detection Method of the Driver's Face and Eye Region for Driving Support System

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Abstract

In recent years, researches of the facial part acquisition system for the automobile driver support has been made actively. So we are developing a driver support system which uses a camera instead of touching with the drivers. In this paper, we use a special photography method to remove the background which disturbs the facial part acquisition. We propose the new method by which only the face region of a driver is stably obtained in the car. Further, the eye region is detected by using the obtained facial region image in order to apply to the detection of the drowsiness.

1 Introduction

Nowadays, the technology to prevent the traffic accident caused by the drivers falling asleep at the wheel is strongly expected[1]. There are many methods on detecting the drowsiness of a driver such as (1) detecting the change of steering action[2][3], (2) measurement of the states of the physiology, for example the driver's heartbeats[4][5], and (3) detecting the opening-and-closing state of eyes by image processing[6]-[8]. But, the method (1) could not detect the drowsiness directly, and it is necessary to measure the many times. Therefore practically the accuracy would not be enough. As for the method (2) it is necessary to equip the driver with some special devices to the body. So it gives a burden to drivers. However, the method (3) that uses the image processing is not only a non-contact system to a driver, but also it can detect the drowsiness of the driver at an early stage. So we are developing a driver support system which uses a camera instead of touching the drivers.

When images are taken in the car by using the camera and the image processing is performed, there are many problems that have to be solved unlike the indoor environment. The camera position is extremely limited, and the simple algorithm is required, because the high-performance computer cannot be installed in the car. A car system must have high accuracy, because it affects people's life. In addition, the lighting environment changes remarkably by time or places, and the image taken in a car has many unnecessary objects.

In this paper, the technique of solving these problems is proposed. We propose a new technique that is capable of detecting only the stable face region both in the daytime and night. Further, we propose the new technique of the eye region detection by using the horizontal direction edge.

2 Outline of the system

The outline of the system is shown in figure 1. To acquire images in the car, the Infrared Rays Light Emitting Diodes (IR-LED) are lit to the face of the driver. The Infrared Rays filter(IR-filter) is attached to a camera. The IR-LED and the camera are installed in the inside of the inner mirror as shown in figure 2.

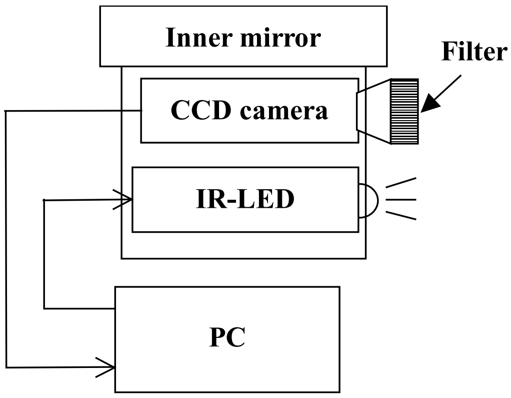


Fig.1 Outline of the system

2.1 Consideration of the camera position

We installed the camera and IR-LED in the inner mirror. The driver always adjusts the angle of an inner mirror before the driving. Even if a seat position is changed, there is surely the face in the central part of the image.

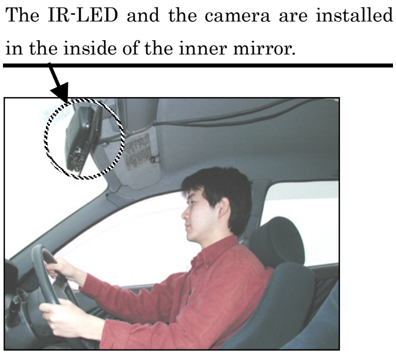


Fig.2 The camera position

2.2 The band path filter and the IR-LED

In this system, the image was taken by attaching the IR-filter to the CCD camera. But when images were taken, the infrared rays from sunlight except for the light of the IR-LED penetrated. Therefore, the halation is occurred in the image during daytime. To reduce the halation, there is a method to adjust the aperture of the camera. In this case, it is difficult to take the images at night with the same aperture value. Therefore, we have to change the aperture value in the day and at the night.

We used the band path IR-filter (BP-IR-filter) as shown in table 1 to solve this problem. Hereby, it becomes possible to reduce the influence of the infrared rays which is included the sunlight in the daytime by allowing only the wavelength zone of the IR-LED to go through. This system was able to reduce the halation, and it does not need changing of the aperture value.

Table 1 The characteristic of the BP-IR-filter

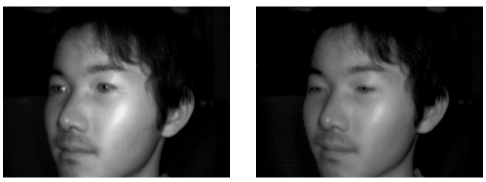
Main transmission wavelength [nm]	880
Half bandwidth [nm]	50

Table 2 The characteristic of the IR-LED

Wavelength of a peak level [nm]		880
Half bandwidth of a spectrum [nm]		40
Response speed	Rising time [ns]	30
	Fall time [ns]	30

(a)IR-filter (b)IR-BP-filter

Fig.3 Example in the daytime



(a)IR-filter (b)IR-BP-filter

Fig.4 Example in the night

The characteristic of the IR-LED that we used is shown in table 2. The wavelength of the IR-LED and the transmission wavelength of this BP-IR-filter are 880nm. The output power level of the IR-LED is set so as not to influence the human body.

Figure 3 is the example in the daytime, figure 4 is the example in the night. Those filters are satisfactory to brightness in the night. But, in the daytime, by the IR-filter, the halation has occurred. For this reason, we re-set up the aperture of a camera, whenever lighting changed. However if this BP-IR-filter is used, halation is restrained as shown in the (b) of the figure 3.

3 Extraction of the face region

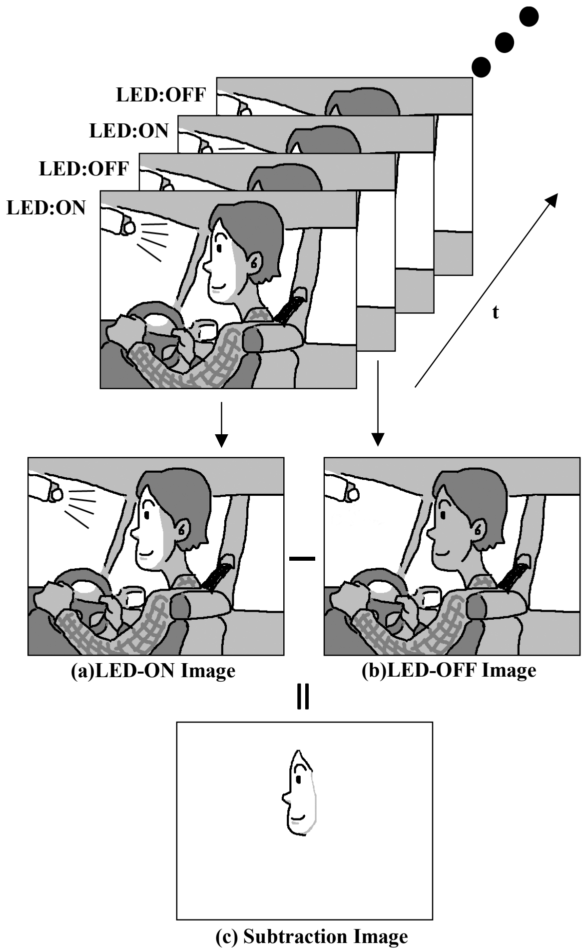


Fig.5 The outline of the face region detection system

The unnecessary object that may cause the miss-detection is included in the images taken in the daytime behind the window. This causes the deterioration of the detection accuracy of the eye region. If the detection of the eye region is performed from the whole image, the processing time will become large. When actual utilization is considered, it is necessary to use the robust face region detection technique under any lighting environments. In this research, the new technique of the face region detection by active lighting of the IR-LED is proposed to reduce the influence of the sunlight in the daytime.

3.1 The outline of the face region detection system

In the first step, the sequential images are taken with blinking the IR-LED turning on and off alternately. The image is taken in the illumination condition turning the IR-LED on as shown in figure 5(a). In the next frame, the IR-LED is turned off, and the image is also taken as shown in figure 5(b). Then, the factor by light other than IR-LED is eliminated by making the subtraction of these two images. The image of the region where was irradiated by the IR-LED is obtained as shown in figure 5(c). By this method, it becomes possible to acquire only the image of the face region. Since the light of the IR-LED does not reach distant place, the background is eliminated by subtraction.

The face region is obtained at 30 frame/sec. by repeating this process sequentially with turning the IR-LED ON-OFF and OFF-ON alternately as shown in figure 6.

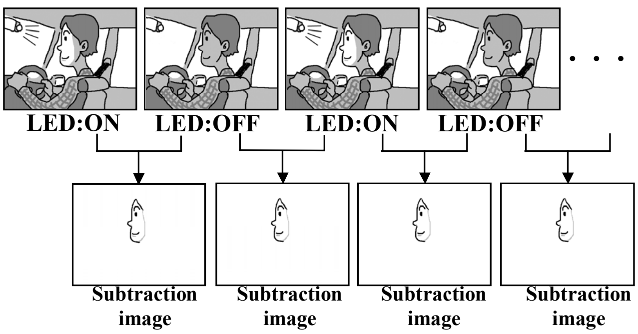
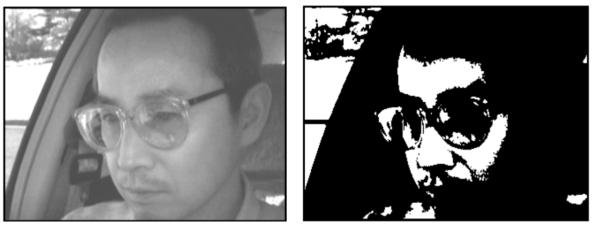


Fig.6 Continuous acquirement of the face region

3.2 Experiments of the face detection

We made experiments on the face region detection by using images in the car. Subjects of this experiment are three persons in the daytime and two persons in the night. We prepared images of 50-sets from each parson. The total number of the image is 250-sets. Subjects were asked to turn the face to the front, the top, the bottom, the left, and the right. These images were equally distributed to 50-sets experimental data. We also performed the face region detection by using the simple binarization for the comparison.



(a) Input image (b) Binarized image

Fig.7 An example of the face region detection by using simple binarization

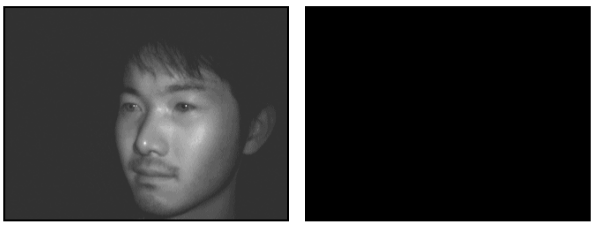
Figure 7 shows an example of the face region detection by the simple binarization. A background remains as shown in the figure 7(b). This phenomenon is caused by the direct sunlight that is brighter than the light of the IR-LED at the point of the background. If a window of a car is large and a seat position is in the front, a face will assimilate to the background and causes the miss-detection. That is, the face region obtained by the simple binarization is influenced by the environment greatly, and it will be very unstable.

Figure 8 is an example of face region detection in the daytime by using our method. When the IR-LED was switched ON and OFF, figure 8(a) and figure 8(b) were obtained. The subtraction of these two images is made, and the binarized image was obtained as figure 8(c). Then, maximal region is detected from this figure, and the final result was shown as square frame in figure 8(d). Consequently, we succeeded in the detection of the face region from the image that contains many backgrounds. Figure 9 is the example taken in the night. Only the face region was detected same as the daytime.

(a) LED-ON image (b) LED-OFF image

(c) Subtraction image (d) Result image

Fig.8 An example by using our system in the daytime



(a) LED-ON image (b) LED-OFF image

(c) Subtraction image (d) Result image

Fig.9 An example by using our system in the night

The comparison experiment of the simple binarization and our system was conducted. The result is shown in table 3. When only a face region was detected without including any backgrounds, we judge the result successful.

Table 3 The result of face region detection

	Simple binarization	Proposed method
In the night [%]	100	100
In the daytime [%]	44	95

The result of this experiment shows that the simple binarization is weak in the daytime. However, our proposed method could detect the face region stably both in the daytime and night. If lighting environment changes, the adjustment of threshold is needed in simple binarization method. However, in our new technique, once the threshold is set up to the output of the IR-LED, changing the threshold does not need even if lighting environment changes. Moreover, since this system consists of only the subtraction and the binarization, processing time is short. Furthermore, we checked that this technique operated to stability from 50*lx* to 65000*lx*.

Next, we detect eye regions using those face region images.

4 Detection of the eye region

We have so far detected the eye region by using a bridge of the nose and the mask pattern of fixed size [9]. However, these methods cannot cope with the change of the direction of a face or the size of eyes. So, we used the horizontal direction edge method that is robust for the change of direction of a face. We pay attention that the distance of the edge corresponding to an upper eyelid and a lower eyelid was near. First, the eye region is divided into the upward edge and the downward edge of the horizontal direction edge. The two edge images are shifted several pixels in the lengthwise direction, and an eye region is detected by combining them. When images are combined, the blur filter operation as Gausian filter is executed to cope with the change of size of the eye.

4.1 Process of detection of the eye region

An example of processing of eye region detection is shown in figure 10. First, from an eye region image as shown in (a), the upward edge and the downward edge of the horizontal direction edge are created as shown in (b) and (c). The blur filter operation is performed to these images as shown in (d) and (e). Next, images of two sheets are shifted several pixels in the lengthwise direction, and are combined. Then, the image is binarized, and it becomes the image as shown in (f). Further, the AND processing is performed when images are combined. By this processing, the region where the position of two edges is distant disappears. That is, the region that the possibility of eyes is low is eliminated. By this, the output result is not influenced by the region containing only one edge such as a sun visor.

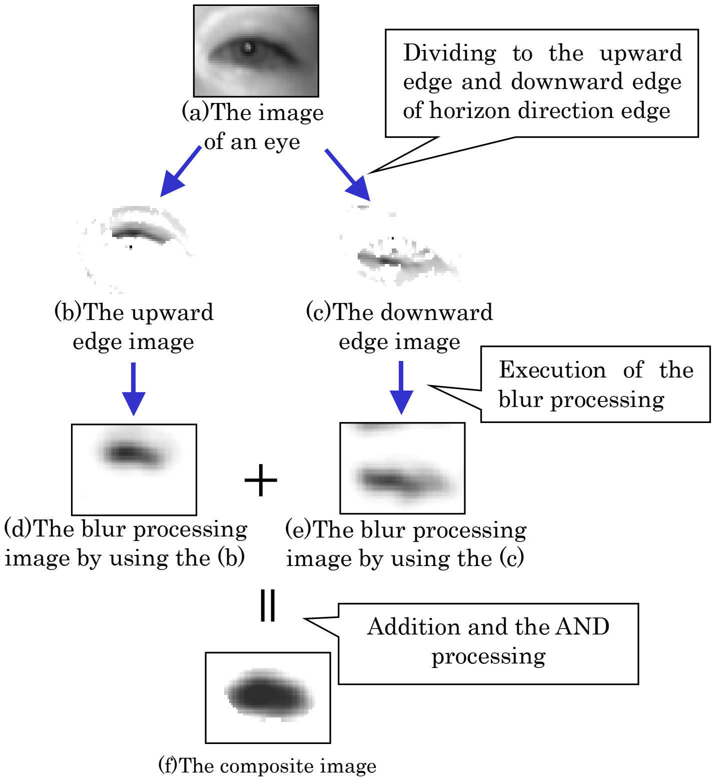


Fig.10 Outline of the eye region detection

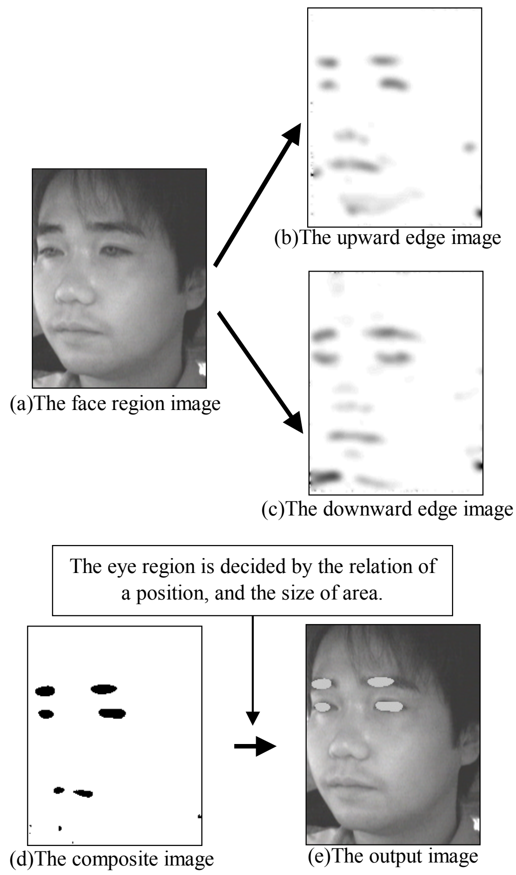


Fig.11 Processing of the image in the car

Figure 11 is an example that the eye region was detected using the image in the car. As shown in (e), the eye regions are detected from the area size and the relation of a position. The eyebrows are also contained in the output. We distinguish that eyes are downside region and the eyebrows is upper region.

4.2 Experiments 1: Detection rate of the eye region

We made experiments by the procedure shown in figure 11. The image after the face region detection was used for experimental data. Subjects are three persons in the daytime and two persons in the night. Direction of a face is towards the front, the left, the right, the upward and downward. The number of data is 250 for five persons. The threshold is set up once for all at the first setout.

Experimental results are shown in table 4 and figure 12. Table 4 shows the detection rate in the daytime and at night, and figure 12 shows detection rates by the direction of the face. Approximately 90% of the detection rate was given as the result of the experiment. Moreover, we recognized that the rate of detection is not different in the daytime and at night. As shown in figure 12, the result of changing the face direction was good except the downward. When the face turned to the bottom, the eye disappeared from the image and there was a case of wrong detection. However, we can assume that the driver is looking aside in this case.

Table 4 The detection rate of the eye region

The detection rate in the night [%]	91.2
The detection rate in the daytime [%]	87.2
The average detection rate [%]	89.2

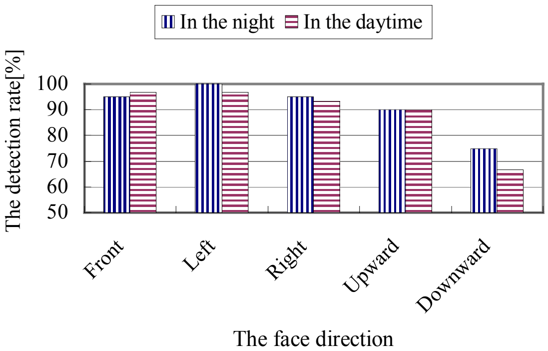


Fig.12 The detection rate by the direction of the face

Figure 13 shows examples which is difficult to detect in which the face is irradiated by the direct sunlight and the sun visor is used. In figure (a), the driver is looking at the left. In figure (b), looking upward, and in figure (c), looking downward. As shown in these figures, the sun visor did not influence. When the driver turns to the bottom, the eye disappears from the image. Therefore, only one of the two eyes is detected.

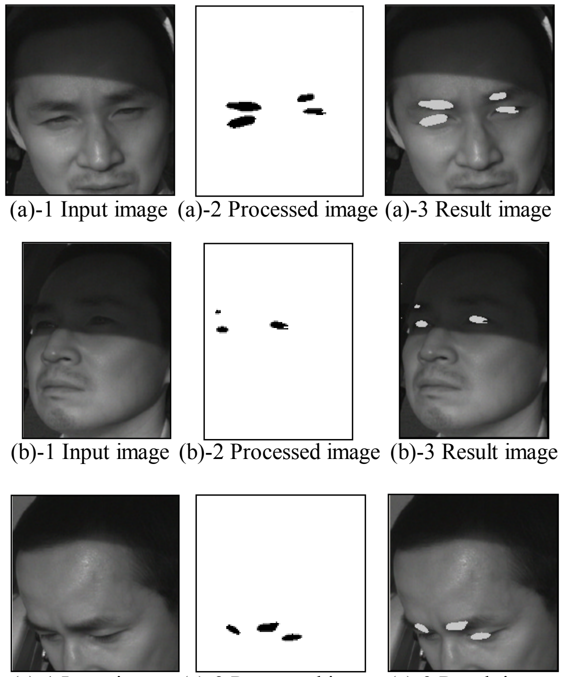


Fig.13 Examples of using sun visor

4.2 Experiment 2: Accuracy by changing size of eyes

Next, we investigated the detection rate by changing the size of eyes. We changed the size of eyes by changing the position of a seat, and experimented. Subjects are three persons in the daytime. The distance from the camera to a face is changed to 60cm, 70cm and 80cm. Direction of a face is towards the front, the left, the right, the upward and downward. The number of data is 225 for three persons. The procedure of processing is the same as the experiment 1. Parameters are adjusted to 70cm, and it was not changed even if the position of a seat is changed.

Table 5 The Accuracy by changing size of eyes

The detection rate of 60cm [%]	85.3
The detection rate of 70cm [%]	94.7
The detection rate of 80cm [%]	74.7
The average detection rate [%]	84.9

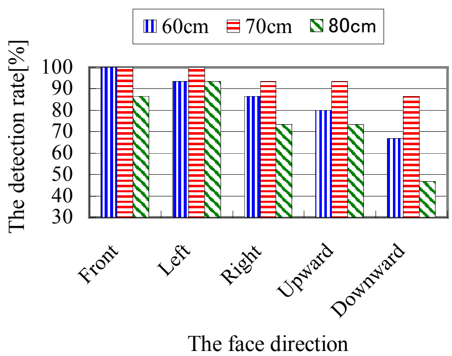


Fig.14 Accuracy by changing size of eyes

The result is shown in table 5 and figure 14. The detection rate of approximately 85% was given. The result of changing the face direction was good except for the downward. This reason is same experiment 1. By this experiment, we confirmed that this system was effective also to change of the size of eyes.

4 Summary

We proposed the new system of a face region detection using active lighting of IR-LED which is not influenced by lighting condition and the background, and the validity of this system was confirmed. Moreover, we proposed the new system of the eye region detection by using the horizontal direction edge which is robust to the change of the face direction and the size of eyes, and the performance of this system was confirmed.

By this research, we realized the effective system which is able to detect the face region and the eye region in the any situation. Moreover this system can detect at high-speed and can cope with the various lighting environment.

From now on, we are going to increase the quantity of experimental data, try to deal with the drivers wearing glasses and apply to the detection of the drowsiness while driving.

References

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