Safe Driving System

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***Abstract*— In the paper, a safe driving system is proposed. The LED light source is designed and placed behind the driver’s head. The successive frames including the driver’s head are acquired by camcorder. The region of concern in the acquired frame is transformed to grey image first. Then, the LED region is segmented. Finally, the variation of the segmented LED area is analyzed. Large area variation will be judged to be abnormal driver’s behaviour and warning to the driver will be issued. The major features of the system are its robustness to violent illumination variation outside the vehicle and sheltered effect to eyes due to sunglasses. Software simulations are also given to demonstrate its effectiveness and robustness.**

***Keywords*— safe driving, LED light source, camcorder, illumination variation, sunglasses**

1. INTRODUCTION

When a driver is drowsy or absent-minded, his perception ability to surrounding environmental, handling ability to the car, and decision ability to traffic situation all diminish. They all easily result in serious traffic accident. Moreover, the illumination outside the vehicle will have violent variation due to road condition and different time in a day. Hence, the development of safe driving monitoring system robust to violent illumination variation is very important to prevent traffic accident and reduce loss of life and property. Actually different brands of car corporations and research centres devote themselves to develop this kind of system over the past decade [1]-[4]. For example, the monitoring system “City safety” is the standard equipment in VOLVO XC60.

Many approaches [5]-[23] have been proposed to detect driver’s drowsiness or inattentiveness. They can be classified into the following four categories.

1) The first category is based on driver's physiological signals such as brain waves, electrocardiogram signal, heart rate, pulse rate, et al. [5]-[8]. It is reasonable to measure these signals to reflect the driver’s drowsiness. However, there exist a gap between measured signal and true physiological state. Moreover, it is necessary to attach sensors to the driver to measure the physiological signal. The attachment will interfere with the driver and limit its practical application.
2) The second category focuses on driver’s head or face state such as head movement, blink rate, eye closure, eyelid movement, direction of eye gaze, mouth shape, pupillary variation, etc. [5], [9]-[12]. To monitor these driver’s states, it just needs camcorder instead of contacting sensors. Well-developed image processing techniques make the category to be a promising approach. However, how to overcome the violent illumination change outside the vehicle or sheltered effect to eyes due to sunglasses is a challenge.
3) Methods [5], [13]-[15] based on vehicle's behavior such as vehicle lateral position, distance between the driver's vehicle and the front car, movement direction, and so forth are the third category. How to overcome the influence of the characteristics of the roadway, road quality, and illumination change is its major challenge.
4) Methods [5], [16]-[18] based on the combination of the above categories are the fourth category. Combination of different approaches is hopeful to obtain more robust safe system.

In the paper, an adaptive safe driving system belonging to the second category is proposed. The major purpose of the system design is to overcome the problems when illumination variation outside the vehicle is violent in different time of a day or in different road condition, and the driver wears the sunglasses.

2. SAFE DRIVING SYSTEM

To monitor the driver's drowsiness or inattentiveness, the safe driving system (SDS) is proposed. Lateral view of the system is shown in Figure 1. In the monitoring system, the camcorder is located in the front of the driver and the LED light source is placed behind the driver's head. Figure 2 shows the designed LED light source. Any head movement will result in the area change of LED region. By analyzing the LED area change, SDS can detect abnormal head movement and issue a correct warning signal.

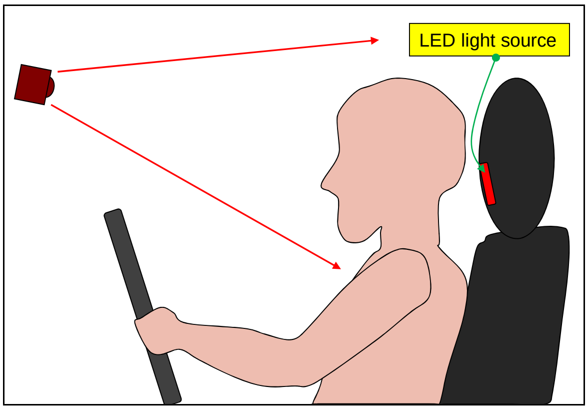

Fig. 1 Lateral view of the adaptive safe driving system

Fig. 2 LED light source behind the driver's head

To monitor the driver's head movement and determine whether the warning is issued or not from the acquired frame, the head movement monitoring algorithm (HMMA) is proposed. The schematic diagram of HMMA is shown in Fig. 3.

To describe the HMMA quantitatively, the following notations are adopted:

- f: color frame of size 540×960,
- $fROI$: region of interest in f of size 46×236,
- fL: luminance component of $fROI$,
- fB: binarization image of fL,
- $fROI_{i,j}^{R}$: red component of pixel (i, j) of $fROI$,
- $fROI_{i,j}^{G}$: green component of pixel (i, j) of $fROI$,
- $fROI_{i,j}^{B}$: blue component of pixel (i, j) of $fROI$,
- $fL_{i,j}$: luminance value of pixel (i, j) of fL,
- $fB_{i,j}$: binary value of pixel (i, j) of fB.

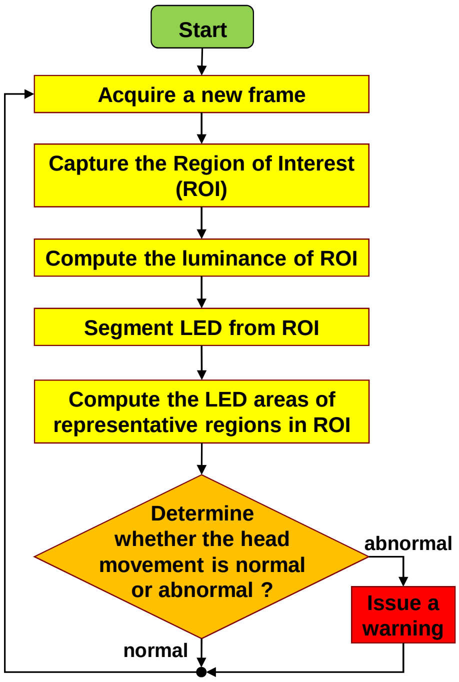

Fig. 3 The head movement monitoring algorithm in SDS

2.1. Acquire a new frame

Use the camcorder to acquire a new frame f.

2.2. Capture the region of interest

Any head movement influences the LED region. To monitor the head movement, we capture the sub-frame $fROI$ including LED as the region of interest (ROI), where

$$fROI = f(400{:}445, 390{:}625)\,. \qquad (1)$$

2.3. Compute the luminance of ROI

Compute the luminance of ROI by

$$fL_{i,j} = 0.299\times fROI_{i,j}^{R} + 0.587\times fROI_{i,j}^{G} + 0.114\times fROI_{i,j}^{B}\,. \qquad (2)$$

2.4. Segment LED from ROI

According to the luminance of ROI, we select threshold 240 to segment LED by

$$fB_{i,j} = \begin{cases} 1 & \text{if } fL_{i,j} > 240 \\ 0 & \text{if } fL_{i,j} \le 240 \end{cases}\,. \qquad (3)$$

2.5. Compute LED areas of representative regions in ROI

The LED areas of seven representative regions are computed by the following schemes:

$$
\begin{aligned}
w &= \sum_{i=1}^{46}\sum_{j=1}^{236} fB_{i,j}, \\
w_l &= \sum_{i=1}^{46}\sum_{j=1}^{100} fB_{i,j}, \quad w_r = \sum_{i=1}^{46}\sum_{j=145}^{236} fB_{i,j}, \\
w_{ul} &= \sum_{i=1}^{15}\sum_{j=1}^{30} fB_{i,j}, \quad w_{ur} = \sum_{i=1}^{15}\sum_{j=226}^{236} fB_{i,j}, \\
w_{ll} &= \sum_{i=35}^{45}\sum_{j=1}^{10} fB_{i,j}, \quad w_{mr} = \sum_{i=18}^{28}\sum_{j=215}^{225} fB_{i,j}.
\end{aligned} \tag{4}
$$

2.6. Determine whether the head movement is normal or abnormal

Set w_{key} to be w_{mr} if $w_{mr} > w_{ll}$ and $w_{ur} < 50$. Otherwise, w_{key} equals w_{ll}. According to w_{key}, HMMA monitors the following conditions for the acquired frame.

Condition 1: $w_{key} < 23$
(w>450 and w_{ul} <200 and w_{ur} <50)
or (w_r >200 and w_{ul} <200 and w_{ur} <45)
or (w_l >219 and w_{ul} <200 and w_{ur} <20)
or (w_r >306)

Condition 2: $23 \le w_{key} < 34$
(w >450 and w_{ul} <200 and w_{ur} <50)
or (w_r >170 and w_{ul} <200 and w_{ur} <54)
or (w_l >447 and w_{ul} <200 and w_{ur} <40)

Condition 3: $34 \le w_{key} < 61$
(1900<w<3200 and w_{ul} <156 and w_{ur} <40)
or (w_r >600 and w_{ul} <200 and w_{ur} <40)
or (w_l >1150 and w_{ul} <200 and w_{ur} <40)

Condition 4: $61 \le w_{key} < 80$
(1560<w<3200 and w_{ul} <20 and w_{ur} <40)
or (w_r >810 and w_{ul} <200 and w_{ur} <40)

Condition 5: $w_{key} \ge 80$
(1900<w<3200 and w_{ul} <20 and w_{ur} <40)
or (w_r >810 and w_{ul} <200 and w_{ur} <40)

If any one of the five conditions happens, HMMA judges the driver's head movement in the present frame is abnormal and issues the warning signal to the driver.

3. SOFTWARE SIMULATION RESULTS

To demonstrate the effectiveness of the proposed SDS, the system is set up in an automobile. We use the vehicle video recorder CASA HDR-550 to record the region around the driver's head. Two strips of SMD LED are adhered to the back cushion behind the driver's head.

We record the region around the driver's head continuously. The video of 60 seconds in the following drivering circumstances is selected. (i) The car goes through the tunnel two times. The illumination variation outside the vehicle is violent. (ii) The driver wears the sunglasses.

We extract 1796 frames from the video. According to the HMMA, software simulations are performed. We capture ROI, compute its luminance, and segment LEDs according to the luminance of ROI. After the LEDs are segmented, we compute the LED areas of seven representative regions in ROI. Whether the head movement is normal or abnormal can be judged by Conditions (1)-(5). The warning result of all the 1796 frames is shown in Fig. 4, where the blue bar denotes that warning to the frame is issued. The complete simulation results of all the 1796 frames are concatenated to a video again. The video is uploaded to YouTube [19].

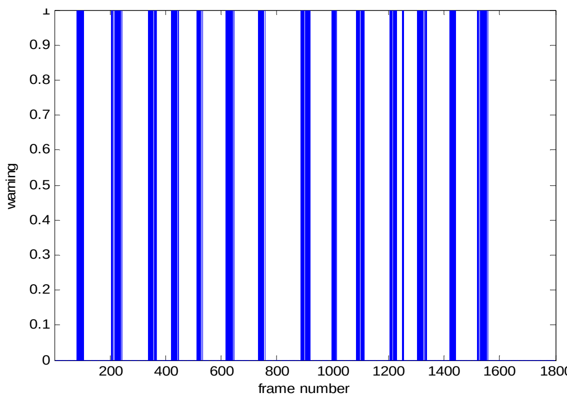

Fig. 4 The warning result of all the 1796 frames.

The ROI is a region of size 46×236. The computational complexity to compute the luminance of ROI, segment it by thresholding, and examine whether the head movement is abnormal by Conditions (1)-(5) is very low.

In the selected video, there are fifteen driver's nods. The video shown in YouTube demonstrates that all the nodding behaviours are detected exactly. Because the twelfth time of the fifteen nods is unobvious, just the 1253th and 1254th frames are detected to be abnormal.

The video shown in YouTube also clearly demonstrates the advantages of the proposed SDS. The driver wears the sunglasses. The automobile he drives goes through the tunnel two times. At the moment that the automobile enters or leaves the tunnel, the illumination variation outside the vehicle is very fiercely. Even so, SDS overcomes the two problems and detects the abnormal head movement correctly.

4. Conclusions

In the paper, a robust safe driving system is proposed. By segmenting the LEDs in the region of interest and analyzing the variation of the LED areas of representative areas according to HMMA, the system can correctly issue warning to the driver when the head movement is abnormal. The features of the proposed system are as follows. (i) The HMMA is a fast algorithm because only the region of interest is monitored and processed. (ii) The system can overcome the violent illumination change when the vehicle goes through the tunnel. (iii) The sheltered effect to eyes due to sunglasses is also overcome. (iv) The cost of the system is cheap.

Finally, we believe that the active safe driving system can greatly benefit by adopting the proposed system.

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