Driver drowsiness monitoring based on yawning detection

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Driver Drowsiness Monitoring Based on Yawning Detection

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***Abstract*—Fatigue and drowsiness of drivers are amongst the significant causes of road accidents. In this paper, we discuss a method for detecting drivers' drowsiness and subsequently alerting them. The aim is to reduce the number of accidents due to drivers fatigue and hence increase the transportation safety. Many special body and face gestures are used as sign of driver fatigue, including yawning, eye tiredness and eye movement, which indicate that the driver is no longer in a proper driving condition. Here, we propose a method of yawning detection based on the changes in the mouth geometric features.**

Keywords-component: Drowsiness Monitoring, face tracking, yawning detection

I. INTRODUCTION

Driver fatigue not only impacts the alertness and response time of the driver but it also increases the chances of being involved in car accidents. National Highway Traffic Safety Administration (NHTSA) analysis data indicates that driving while drowsy is a contributing factor to 22 to 24 percent of car crashes, and that driving while drowsy results in a four- to six-times higher near-crash/crash risk relative to alert drivers [1]. This high accident rate is due to the fact that sleepy drivers fail to take correct actions prior to a collision. An important irony in driver's fatigue is that the driver may be too tired to realize his own level of drowsiness. This important problem is often ignored by the driver. Therefore, the use of assisting systems that monitor a driver's level of vigilance is crucial to prevent road accidents. These systems should then alert the driver in the case of drowsiness or inattention.

Some warning signs that can be measured as indications of driver fatigue are: daydreaming while on the road, driving over the center line, yawning, feeling impatient, feeling stiff, heavy eyes and reacting slowly. There have been intensive research works done to detect drowsiness of drivers, based on the above mentioned gestures of body (i.e. eye motion detection and yawning detection), as we shall see in section II. However, our approach is more robust against false detections, and is also more practical to implement. In our method, the driver's face is continuously recorded using a camera that is installed under the front mirror. In order to detect the yawn, the first step is to detect and track the face using the series of frame shots taken by the camera. We can then detect the location of the eyes and the mouth in the detected face. It should be noted that even though we don't process the eye gestures for yawning detection, the location of the eyes in the face is used as a way to verify the location of the segmented mouth. This makes the mouth segmentation procedure more robust to false detections. The mouth geometrical features are then used to detect the yawn. The system will alert the driver of his fatigue and the improper driving situation in case of yawning detection.

This paper is organized as follows: in section II the related work about the detection of driver fatigue is presented. Section III describes the method of approaching the goal of the paper. Experimental results are shown on section IV and finally section V presents the conclusion and future studies.

II. RELATED WORK

The work in [2] proposes the detection of the face region using the difference image between two images. Driver's yawn is then detected based on the distance between the midpoint of nostrils and the chin. [3] uses Gravity-Center template to detect the face. It then uses grey projection and Gabor wavelets to detect the mouth corners. Finally LDA is applied to classify feature vectors to detect yawning. [4] presents a system where the face is located through Viola-Jones face detection method in a video frame. Then, a mouth window is extracted from the face region, in which lips are searched through spatial fuzzy c-means (s-FCM) clustering. [5] takes advantage of two cameras: a low resolution camera for the face and a high resolution one for the mouth. It then uses haar-like features to detect driver's mouth and yawning is detected by the ratio of mouth height and width. The work presented in [6] also takes advantage of some mouth geometrical features to detect yawning.

Our work is different from the related literature in two aspects. First, we reduce the high level of detection dependency on the face geometry in order to make our algorithm more robust to changes in the subject. Second, we avoid the use of complex algorithms and classifiers in order to have a realistic implementation within an actual camera system in the car, while maintaining the same level of detection efficiency. We have worked with Cognivue Corp., whose products include such in-car cameras, to ensure that our proposed system is actually feasible and practical for real implementations.

III. PROPOSED APPROACH

The driver fatigue detection procedure consists of different phases to properly analyze changes in the mouth of the driver. These phases are categorized as follow and each phase will be introduced in detail in the following sections:

1. Face Detection
2. Eye Detection
3. Mouth Detection
4. Face Tracking
5. Yawning Detection

The overall system diagram is shown in Figure 1. The details of each step will be further explained in the following subsections.

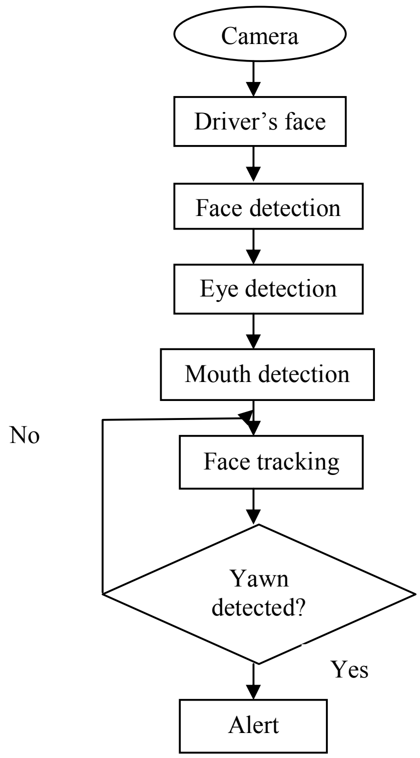

Figure 1. System Diagram

A. Face detection

Given a single image, the goal of face detection is to identify all image regions, which contain a face regardless of its position, orientation, and lighting conditions. Such a problem is challenging because faces are nonrigid and have a high degree of variability in size, shape, color, and texture [7]. It is basically assumed that the camera is installed inside the vehicle facing the driver at a fixed angle. Therefore the problem of relative camera-face pose is less challenging in our case while head position might still vary from driver to driver. There is also a great deal of variability among faces including shape, color, and size. Presence of facial features such as beards, mustaches, and glasses can also make a great deal of difference. The other important factor is the lighting conditions. This is mainly affected by the environment light that can change depending on the time and weather conditions.

Keeping all the above considerations in mind, the most functional way to detect face is by detecting the skin color and texture. However, it should be noted that the detections scheme should be invariant to skin type and change in lighting conditions. Therefore we take advantage of a set of bounding rules for different color space (RGB, YCbCr and HSV) in order to improve the detection efficiency [8]. RGB color space is used to detect skin color at uniform or lateral daylight illumination and under flashlight illumination:

(1)

(R > 95) AND (G > 40) AND (B > 20) AND (max{R, G, B} - min{R, G, B} > 15) AND (|R - G| > 15) AND (R > G) AND (R > B) AND (R > 220) AND (G > 210) AND (B > 170) AND (R > B) AND (G > B)

Cb-Cr color space is a strong determination of skin color. The following rules apply to this color space:

(2)

(Cr <= 1.5862 * Cb + 20) AND
(Cr >= 0.3448 * Cb + 76.2069) AND
(Cr >= -4.5652 * Cb + 234.5652) AND
(Cr <= -1.15 * Cb + 301.75) AND
(Cr <= -2.2857 * Cb + 432.85)

The last space to be used is the HSV space. Hue values exhibit the most noticeable separation between skin and non-skin regions.

H < 25 and H > 230 (3)

The result of the skin location technique is a black and white image which highlights the skin location by converting the face to white and the background and the areas around the driver to black. This background elimination reduces the subsequent errors due to false object detection in the background. The face is detected by finding the biggest white connected component and will cut that area.

B. Face tracking

Once the face is detected, we can use the detected face as a template for tracking the face in the upcoming frames. The basic idea used in the tracking algorithm is to estimate the location of the face based on Kalman filter motion tracking. We can now assume that the face is located in the neighborhood of the estimated location. In order to find the real position of the face, we use the template from face tracking and perform template matching in the above neighborhood. The location of the face is then found as the point where the correlation of the template and the image located around that point is maximum. If the correlation results go below a certain threshold, the system loses track of the face. Therefore, it goes back to face tracking step.

C. Eye detection

After detecting the face, the location of the eyes will be detected. The main reason behind locating the eyes is to use them as a verification method in order to make sure that the location of the mouth in face is correctly detected (using the geometrical relation between eyes and mouth in human face).

In order to detect the eyes, the eye maps based on chrominance components are built [9] according to the following equation:

$$\text{Eye\_location} = \frac{1}{3}\left\{(C_b)^2 + (C_r)^2 + \left(\frac{C_b}{C_r}\right)\right\} \qquad (4)$$

The eye map highlights the eyes regions. We can then convert the eyemap image to a black and white image using proper thresholding. This new image is supposed to include the eyes in white while the rest is all black. However, several pre-processing steps including erosion, dilation and finding the biggest connected components as eyes are required. Moreover, we use some geometrical features of the eyes in the final step to reject the false detections. Therefore we do not use the geometrical features for detection and we rather use them only for verification purpose.

D. *Mouth detection*

The next step towards yawning detection is to find the location of mouth and the lips. To do so, mouth area will be segmented in the face. The strong difference between lips color and face color is used in our method. In the mouth region, the red color is the strongest component while the blue component is the weakest [9]. Usually the mouth area is detected based on color information, after the face is located. The following equations are used to generate the mouth map.

$$\text{Mouth\_map} = (C_r)^2 \times \left((C_r)^2 - \frac{\eta \times C_r}{C_b}\right)^2 \qquad (5)$$

$$\eta = 0.95 \frac{\frac{1}{n}\sum_{(x,y)} C_r(x,y)^2}{\frac{1}{n}\sum_{(x,y)}\left(C_r(x,y) \big/ C_b(x,y)\right)} \qquad (6)$$

The mouth map will then go through some post processing steps such as black and white conversion, erosion, dilation and finding the biggest connected components in the same way as the eye detection scheme. The geometrical features of the face and relative location of the mouth with respect to eyes can be exploited in this step to verify the validity of the detected mouth.

E. *Yawn detection*

Yawning detection is performed in two main steps: in the first step we detect the yawn component in the face independent of the mouth location. This component is basically the hole in the mouth as the results of wide mouth opening. In the second step we will use mouth location to verify the validity of the detected component.

After skin segmentation, the largest hole located inside the face is selected as the candidate for a yawning mouth. This hole is actually related to a non-skin area inside the face that can be related to eyes, mouth or open mouth. It can be assumed that the open mouth will be the largest of the three in a yawning state. In this way a candidate for yawning mouth is located. We will then use the information from the detected mouth to verify the detected yawning mouth. The versification criteria is the number of pixels located in the yawning mouth with respect to the number of mouth pixels as well as the relative location of the open mouth with respect to the lips.

IV. EXPERIMENTAL EVALUATION

We have applied the face detection algorithm to more than 500 images with different characteristics. The images are taken with various conditions such as different light reflection and directional lightings. The facial features are also considered in our evaluations including skin color, haircuts, beard, and eye glasses. Figure 2 shows the results of our algorithm on several images from Caltech face data base [10].

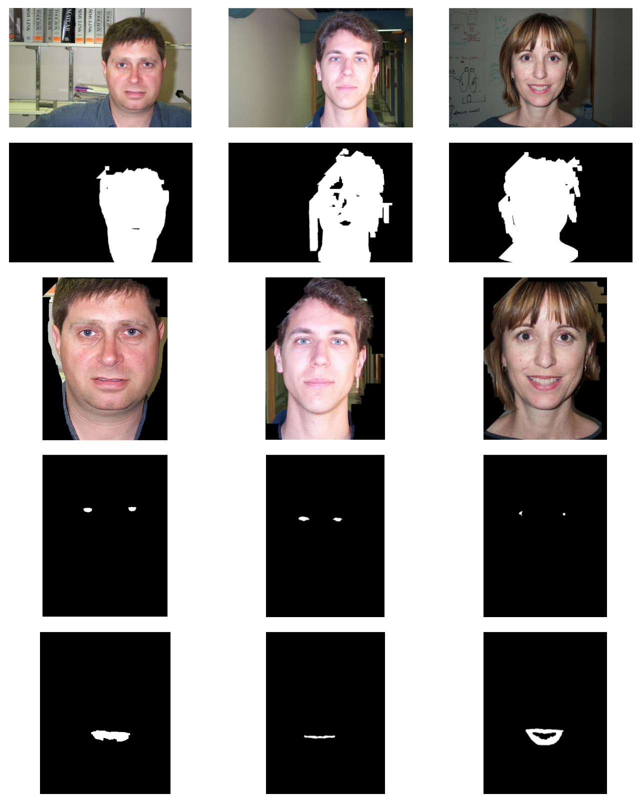

Figure 2. Face feature detection

Following the detection of the face, the eyes, and the lips, the next step is to detect the possibility of a yawning mouth as explained in the previous section. Figure 3. demonstrates the result of face detection as well as yawing detection for a sample image. As can be seen in the figure, the algorithm is able to accurately detect the face as well as the yawning mouth. In the final version of this extended abstract, we will present more results with more variations in the faces.

V. CONCLUSION

This article introduced a new method for detection of driver drowsiness, based on yawing action. The proposed method is based on number of algorithms, which are insensitive to the changes in lighting conditions, skin types, and geometrical facial features. The robustness of implemented technique is due to the fact that several verification criteria are used to avoid false detections. Moreover, we have chosen to avoid complex algorithms in order to be one step closer to the real implementation of the system.

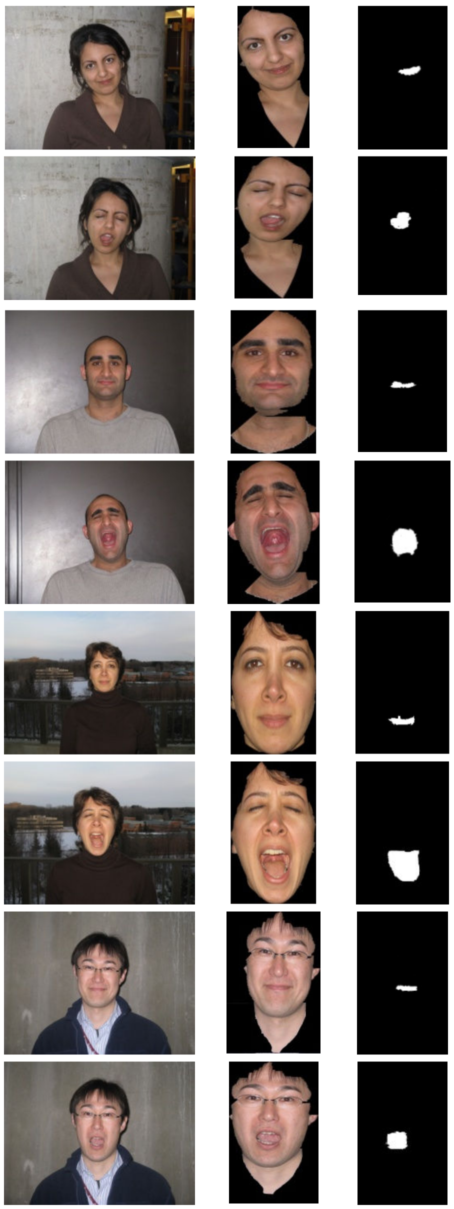

Figure 3. Yawn detecion

VI. ACKNOWLEDGMENT

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