Efficient Measurement of the Eye Blinking by Using Decision Function for Intelligent Vehicles

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Abstract. In this paper, we propose an efficient measurement of the eye blinking for drowsy driver detection system that is one of the driver safety systems for the intelligent vehicle. However, during the real driving in the daytime, driver's face is exposed to various illuminations. It makes too difficult to monitor driver's eye blinking. Therefore, we propose efficient formation of the cascaded form of Support Vector Machines (SVM) as eye verification to boost the accuracy of eye detection. Furthermore, for an efficient measurement of eye blinking, we newly define decision function that is based on the measure of eyelid movement and the weight generated by the eye classifier. In the experiments, we can show the reliable performance for our own test data acquired during a real driving in the various illumination conditions. Furthermore, through our proposed method, we use detected eye blinking for Drowsy Driver Detection System.

Keywords: Eye Blinking Detection, Eye Detection, Drowsy Detection, Cascaded SVM.

1 Introduction

In the safety driving application related with driver's drowsiness, many computer vision-based systems have been successfully applying to real application because it is quite not only accurate but also nonintrusive method for a driver [4], [5], [8].

However, this type of approach is very sensitive to change in illumination [9]. To solve these problems, some systems used the pupil reaction against infrared light pupil reaction as the difference between pupil which appears bright and that which appears dark [4], [5], [8], [9]. However, this kind of research has mainly been performed in the indoor studio without the interruption of infrared illumination from sunlight.

In this paper, we extend our previous approach that tolerates various illuminations changing not only in the daytime but also at night. In the proposed our system, we propose the eye verification by using two-level cascaded SVM that is newly configured. Moreover, we newly define decision function based on eyelid-movement and the weight generated by the eye classifier for detecting eye closed state. Open eye state and closed eye states are distinguished by using the decision function. The remainder of this paper is organized as follows. In Section 2, we describe a robust eye detection method. In Section 3, we configure the classifiers with the two level cascade form of SVM (Two-Level Cascaded SVM) for the eye verification. In Section 4, we

test the decision function for the measure of eye blinking. Experimental results and the estimation of our system are provided in Section 5, and finally we make a conclusion in Section 6.

2 Extraction of Eye Candidates

The input frame includes both the driver's face and the background which are parts of the vehicle as well as scenery outside the car. In order to measure eye blinking, the position of eyes should be detected. Eye corner filter is a fast and reliable preprocessing method for eye detection. In this paper, the eye corner filter is partially used to detect suitable candidates of eye region as [3].

As input frame is convoluted with the filter, we can detect the positive areas over the threshold. The threshold is determined to take 10% from high rank of the result by a convolution with total eye area. Each positive area detected by eye corner filter is cropped with 5 pixels margins from the boundary of positive area as eye candidates if each positive area has a reasonable ratio of horizontal length to vertical length. Cropped eye candidates are normalized the size of 41 by 21 for the eye verification.

3 Eye Detection Using Two-Level Cascaded SVM

In this section, we proposed a novel efficient verification scheme using SVM. In general, eye verification deals with the two-class problem of the eye vs. the non-eye. However, the variation within eye class is large due to the inhomogeneity of open and closed eye data. This fact drops down the verification performance.

Therefore, we considered three classes: open eye, closed eye and non-eye and if filtered eye candidates are classified as open or closed eye, we verified it as the eye. For computational efficiency, we evaluated the SVM with the sequential evaluation algorithm [9] that we called the cascaded SVM. Considering the three classes, we designed the verification procedure with the two-level cascaded SVM. First classifier represents a series of classifiers for open eyes and non-eyes and Second classifier represents a series of classifiers for closed eyes and non-eyes.

4 Eyelid Movement Estimation

In this section, we propose the decision function for eyelid movement estimation. We can determine open and closed eyes using a decision function based on the state of eyelid as follows. Fig.1 illustrates the angles between eye corners and the top of upper eyelid. we define the open degree θ of the eye that is calculate absolute summation of $\theta_L(x)$ and $\theta_R(x)$ as and the marginal value of the open eye detector f^o described in the previous section.

Fig. 1. The measurement of eyelid movements

the open eye classifier f_D is defined as

$$f_D(\mathbf{x}) = w_1 \theta(\mathbf{x}) + w_2 f^O(\mathbf{x}). \quad (1)$$

where weights w_1 and w_2 specify the relative importance of $\theta(\mathbf{x})$ and $f^O(\mathbf{x})$. Here, the value of $f^O(\mathbf{x})$ is defined by $f_m^O(\mathbf{x})$ if the patch $\mathbf{x}$ has negative value at some layer $m(<N_z)$ during the sequential evaluation in first classifier, or $f_{N_z}^O(\mathbf{x})$ otherwise. The threshold T for the decision function f_D can be defined as

$$T = w_1 \theta_T + w_2 \varepsilon_T. \quad (2)$$

In (2), θ_T is a person-specific threshold for the open degree of the eye. It is determined by a quarter of maximum degree of open eyes during first three seconds in the beginning. The constant ε_T is a person-independent threshold that is usually accepted as a small value, say 0.05. Using (1) and (2), we determine the patch $\mathbf{x}$ as the open eye if decision function is over the threshold T .

5 Experiments

In this experiment, we assume that eye detection and the measurement of eye blinking strongly depend on illumination change during real driving, regardless of nondrowsy state or drowsy state. Proposed system consists of three parts; eye detection part, verification part, and eyelid movement estimation part, we define novel decision function for eye blinking adapted for each driver.

Fig. 2. Results of the eye detection process under various illumination conditions

Fig. 2. represents the results of the eye detection process. In the Fig. 2., two eye corner points and a top point of eyelid are also accurately detected in the various illuminations.

6 Conclusion

For robust eye detection, we newly designed two-level cascade form of SVM. We also proposed the decision function for the measure of eye blinking. This function could make more robust decision for the measure of eye blinking. Through our experiments, in the illumination circumstance as a daytime, our proposed method showed the outperforming the conventional method that use a difference between bright pupil and dark pupil by using pupil reaction against infrared light. In the future work, we will integrate this proposed algorithm with our Drowsy Driver Detection System (DDDS).

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