EYE BLINK DETECTION USING INTENSITY VERTICAL PROJECTION

Hai DINH, Emil JOVANOV and Reza ADHAMI
Dept. Electrical and Computer Engineering, University of Alabama in Huntsville
Huntsville, Alabama, USA

ABSTRACT

Blinking is a spontaneous or voluntary action of human eyes. It has long been used for human-machine communication and human physiological detection. In these applications, detecting the eye's states, opened or closed, is an important step and affects the accuracy of detecting human intention or physiological states. In this paper, we present a robust method to detect eye blink based on the intensity vertical projection of eye's image. Unlike many previous works on eye blink detection based on edges of images, our work addresses blink detection by using the intensity of images. The method can deal with the variation of user's eye shape and distances between users and camera.

Keywords: Eye Blink, Vertical Projection, Drowsiness, Viola-Jones

1. INTRODUCTION

Eye blink and eye movement have been used for both human-machine communication to help people with disability [3, 8] and human physiological detection to improve driving safety [2]. Reports show that drowsiness is the major cause of fatal accident [1-2]. The drowsiness increase when we drive at night, in a long trip, or in uniform and monotonous roads. Many projects had been launched in Europe such as SAVE-1996 and AWAKE-2000 programs to address the drowsiness issue in drivers. There are many approaches addressing this issue such as analyzing driver behavior (i.e. steering wheel and pedal movements), mouth opening or heart rate. However, the electrode attachments make those methods intrusive and inconvenient to employ. Recent researches focus on non-intrusive approaches such as using camera to detect eye blink [1-2]. Despite promising results, they face some problems of accuracy of blink detection, variance of eyes' shape or users' movement. In this paper, we propose a new method for eye blink detection by using intensity vertical projection.

2. EXISTING APPROACHES

Applications employed eye blink detection or eye movement tracking for either communication or physiological detection are classified into two approaches: biological and optical approaches.

Biological Approaches: Biological approaches are techniques evaluating and recording the electrical activity produced by human brain, muscle, or retina. Those signals change when a person blinks or moves their eyeballs. Reference [3] proposed a method using eye blinks to activate home lighting system. This application provides an assistive communication for people with disabilities. Electrodes are placed on forehead, earlobe, and occiput to measure brain's spontaneous activity signal (Electro-encephalography, EEG). In order to accurately detect users' intent, the paper analyzed types of blink to differentiate the intentional blinks and unintentional ones. Based on that analysis, patterns of blinks are chosen so that the voluntary blinks, which we make purposely, do not interfere or are not misrecognized with other blinks. Although successfully detect eye blinks with 85% accuracy, the system fail to detect the eye movements which contain artifacts from spontaneous blinks and eyelid movement.

Reference [4] proposed a method using the resting potential of retina (Electrooculography, EOG) instead of EEG for eye mimicking in animation. The authors measure signals from biopotential electrodes placed on forehead and corners of eyes. Authors claim that eyeball orientation could be estimated by using EOG. The estimation requires signal calibration due to variety of personal characteristics and precision of electrodes placement. A detailed method for estimation has not yet been described, and the results also focus only on blink detection. Eye blinks are marked by high amplitude pulses, which extracted by subtracting original signal with signal led through median filter. Eye blinks and eyeball position are then incorporated to produce the appropriate values of morphing goals of an animated character in the computer animation.

In summary, the biological approaches can be used for blink detection but they are relative expensive and bulky. The usage of electrodes attached to human heads also makes it intrusive and inconvenient. This makes it more difficult to apply in systems that require mobility such as driver's drowsiness detection.

Optical Approaches: Optical approaches are methods using motion or pattern of objects in an image sequence. Object recognition algorithms provide accurate methods to detect eyes which have been integrated into a broad variety of applications. The optical approaches are divided into two sub methods: active and passive methods.

Active methods use infrared (IR) illumination to exploit physical properties of eyes. In [5], the red-eye effect, which occurs when using a flash very close to the camera lens, is exploited. Much of the light from the flash passes into the eye through the pupil, reflects off the fundus at the back of the eyeball and out through the pupil. Normal visible light can also create this effect, but IR light is preferred because it does not make users uncomfortable. The system includes on-axis and off-axis IR LEDs. Those LEDs alternately turn on and off while camera taking pictures. The on-axis LEDs create images with bright pupil and off-axis LEDs create images with dark pupil. Those interlaced images are subtracted and applied a threshold filter to get the difference image. Connected component algorithm labels white pixels into groups and then filters those which contain less than three pixels. Probabilistic principal component analysis (PPCA) is used to classify candidates. Each candidate's texture is projected into both eye and non-eye vector spaces which were trained by sets of images. The probability for a particular candidate belongs to either eye or non-eye space is calculated, and then Kalman filter are used to track eyes. The disadvantages are that the method requires IR sources. Furthermore, frame subtraction is sensible to light changing and motion artifact.

The passive methods are mere image processing even some of them still use IR LEDs to deal with ill-illuminated environments such as in dark room or at night. The algorithms vary from detecting eyelid movement or pupil/iris appearances. The driver vigilance diagnostic system [2] applies passive optical method for driver's drowsiness detection. The system detects eyes by initially searching the whole image to locate of face's and eye's features such as eye corners, corners of the mouth and the eyebrows. After initialization, eyes are tracked by using geometrically constrained Kalman filter. The distance between upper and lower eyelids is used to judge the state of eyes. The upper eyelid is modeled by a second degree curve and the lower eyelid is modeled by the line on edge eye region. In comparison with biological approach, this system can detect not only eye blink, but the blink amplitude, the opening degree of eye before and after blink. Detected blinks are classified into short, long, very long, and sleepy blink based on their duration. A fuzzy diagnostic is employed to deal with variability of blinking behavior. The numbers of blink in each category are counted in a time frame ΔT and multiplied by its type's degree to provide the driver vigilance level such as alert, slightly drowsy, drowsy and sleepy.

Reference [1] uses the distance between eyelids for blink detection. Eyes are located by using Viola-Jones object detection algorithm [7] which combines integral image representation and Adaboost classifier to detect objects fast. The detected eye areas are then cropped aligned and tracked by using Lucas-Kanade optical flow. Eyelids are extracted by applying 2D Gabor filter on eye regions. The Gabor filter responds strongly to edges with specific angle vector depended on the orientation angle. The connected component is used to label objects and filter out objects which contain small number of pixels. The largest arcs will be considered eyelids. The distance between those arcs is the opening of the eyes. If it is smaller than a threshold, eyes are considered closed. The improvement of the approach is that it uses Gabor filter instead of normal edge detection as in [2]. Authors claim that the system accuracy is 100%, robust to noise and variety of human eyes. The error of eye detection has not been mentioned. The speed of human head movement also has not considered and, as mentioned by author, it must guarantee that the eye image must have same size, heads rotation, and symmetry between right and left.

In summary, optical approaches are non-intrusive and more convenient. The improving of computational power makes it wearable.

3. PROPOSED METHOD

Intensity Vertical Projection Analysis: Intensity Vertical Projection (IVP) is the total intensity of object pixels in each row. As seen in Figure 1, the eyebrow and iris areas are supposed to be darker than the skin. Hence, there will be two local minima of IVP represent their centers (point A and B). The maximum between those is the center of the skin area between eyebrow and iris (point C).

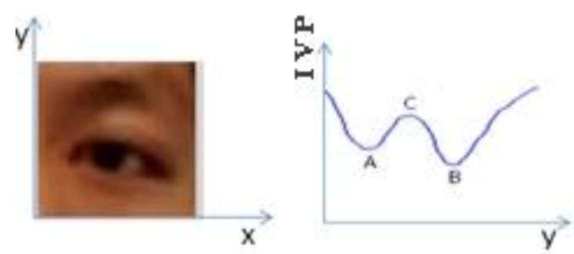

Figure 1. Eye image and IVP.

When the eye is closed, the second local minimum is now the center of the eyelids. Because the skin area is expanded when eye is closed, the IVP become wider around C and narrower around B. This is not depended on user as seen in Figure 2, note that for more convenient comparisons, eye images are rotated ninety degree in this figure.

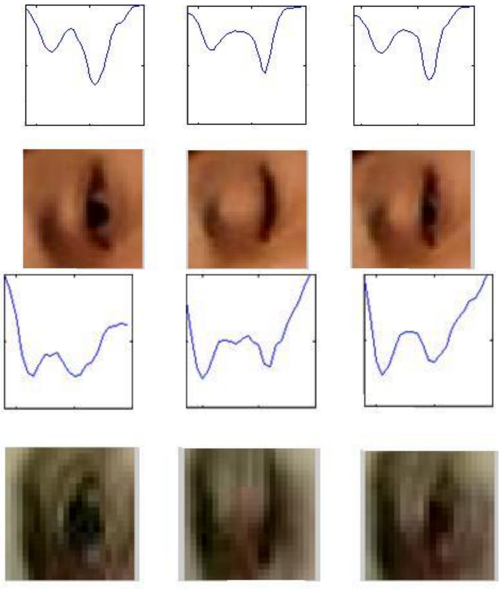

Figure 2. Opened, closed, and half-closed eyes' IPV two different users.

We define the eye opening is the ratio between iris area over the skin area. This ratio can be computed by calculate the ratio of intersection segments between IVP and the adjustment line. The line is defined as 80% of intensity at center of skin area.

$$Eye\ opening = \frac{FE}{ED} \quad (1)$$

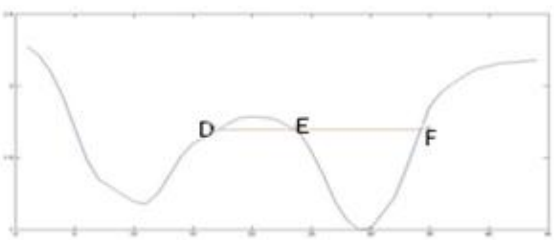

Figure 3. Eye opening parameter.

If the eye opening ratio is larger than a threshold, the eye is considered opened. Otherwise, it's considered closed.

System Overview: Our eye blink detection system includes three main steps as in Figure 4.

Figure 4. System's block diagram.

Video sources are images captured from webcam or loaded from videos. To detect user's eyes, Viola-Jones detection algorithm is applied. The system first looks for user's face and then searches for eyes within detected face. Note that the eye can be found directly in the image without the face detection step, but a two-step detection increases the confidence of detected eyes. The right eye region then will be cropped and used for eye opening calculation at each image frame. Figure 5 shows the system graphical-user-interface (GUI). The value of blink graph is one when eye is closed.

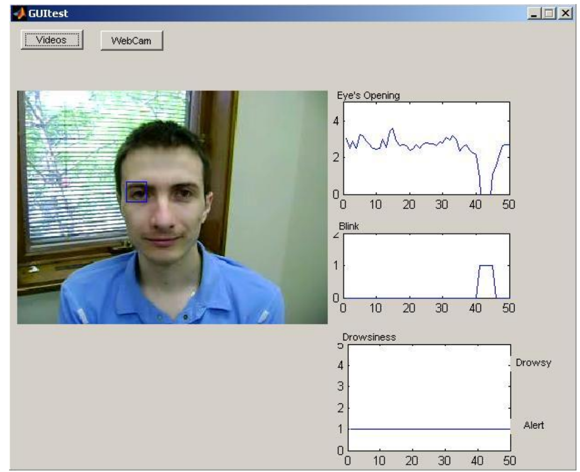

Figure 5. System GUI.

4. EXPERIMENTATION

The system runs on ACER Extensa 5420 with AMD Athlon X2 1.9 GHz CPU, 2G RAM. Videos are taken from Sony camera 10.2 mega pixels and save in avi format. The source code is developed in Matlab and can run without additional library. The trained haar classifier for Viola-Jones detection algorithm is from OpenCV website in the form of an xml file.

Result of Blink Detection: The system is tested with both static and dynamic (moving) users. The moving user makes head-movement left, right, closer and further from camera. The opening ratio is marked by red crosses for opened eyes and blue circles for closed eyes. The eye's statuses are manually checked.

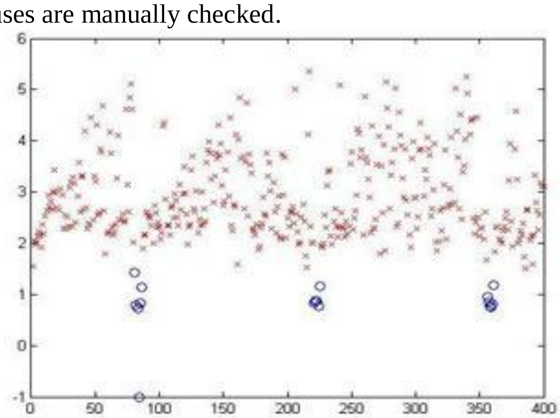

Figure 6. Eye Opening Ratio of static user.

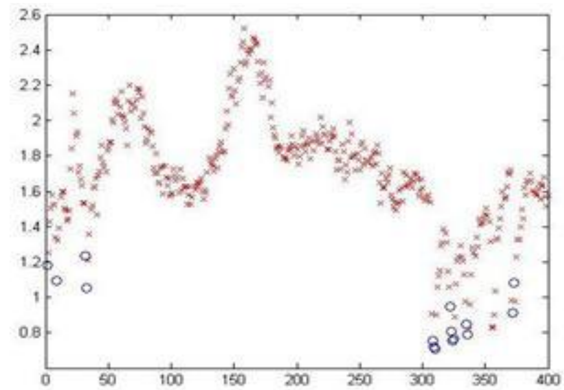

Figure 7. Eye Opening Ratio of dynamic user.

As seen in Figures 6 and 7, the opened and closed eyes can be distinguished by the opening ratio. Figures 8 and 9 show the result for blink detection from the system in comparison with manually checked result. The ratio threshold is set at 1.2 on both videos.

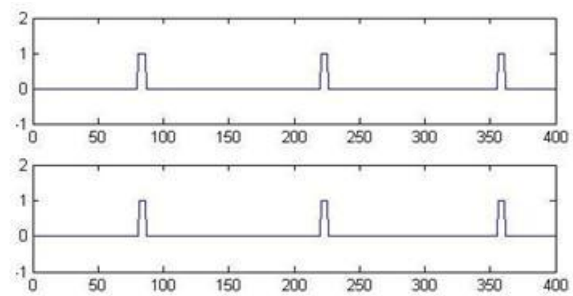

Figure 8. Blink detection result comparison between our system and manual check of static user.

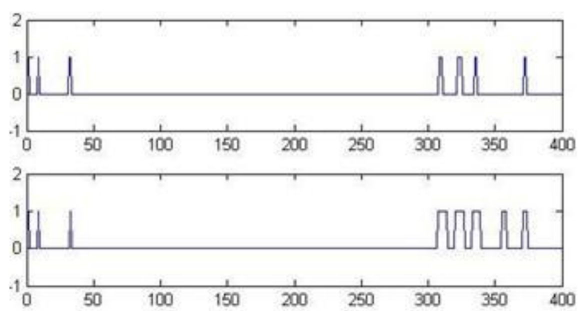

Figure 9. Blink detection result comparison between our system and manual check of dynamic user.

The accuracy is 100% when the user does not move. For the second video, there is one false positive blink, and the accuracy of eye status (opened or closed) is 94.8%.

Drowsiness Detection: The result from blink detection can be used to detect physiological state of drivers. The drowsiness signals, such as vibrates or alarm sounds, are turned on if the system detect that the driver has more than 2 long blinks (defined by the duration of closed eye) and the opening ratio is small after those blinks.

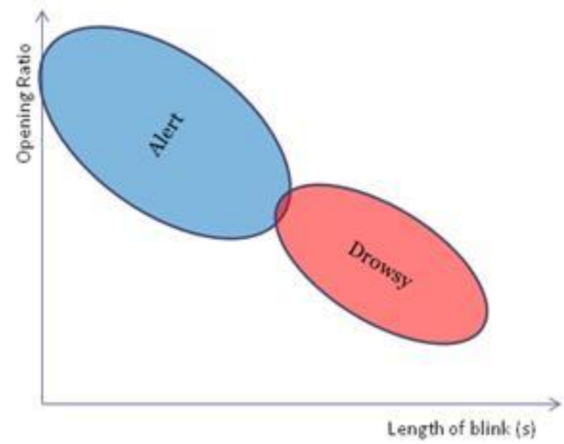

Figure 10. Drowsiness detection.

5. CONCLUSIONS

This paper proposes a new and simple method for eye blink detection by using intensity vertical projection. The proposed method calculates the opening ratio from the vertical projection of images' intensity to detect eye's states. The proposed method is validated using videos of different users. The results are very comparable to manual measurement. Another advantage of the proposed method is that it robust again the variation of eye shapes and eye movements.

6. REFERENCES

[1] Arai, K. and Mardivanto, R., "Real Time Blinking Detection Based on Gabor Filter," **International Journal of Human Computer Interaction**, 2010.

[2] Boverie, S. and Giralt, A., "Driver vigilance diagnostic based on eyelid movement observation," **The International Federation of Automatic Control, Proceedings of the 17th World Congress**. Seoul, Korea 6-11 July 2008.

[3] Rani, M.S.A. and Mansor, W., "Detection of Eye Blinks From EEG Signals for Home Lighting System Activation," **Proceeding of the 6th International Symposium on Mechatronics and its Applications (ISMA09)**. Sharjah, UAE 24-26 March 2009.

[4] Krupinski, R. and Mazurek, P., "Estimation of Eye Blinking Using Biopotentials Measurements for Computer Animation Applications," **Springer-Verlag Berlin Heidelberg**, 2009.

[5] Haro, A., Flickner, M. and Essa, I., "Detecting and Tracking Eyes by Using Their Physiological Properties, Dynamics, and Appearance," **Proceedings of Computer Vision and Pattern Recognition 2000**, pp. 163-168.

[6] Wang, P., Green, M. B., Ji, Q. and Wayman, J., "Automatic Eye Detection and Its Validation," **Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition 2005**.

[7] Viola, P. and Jones, M., "Robust Real Time Object Detection," **Second International Workshop on Statistical and Computational Theories of Vision-Modeling, Learning, Computing, and Sampling**. Vancouver, Canada, July 2001.

[8] Tobii Technology, ***www.tobii.com***