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Performance Analysis of Real-Time Eye Blink Detector for Varying Lighting Conditions and User Distance from the Camera

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Abstract – This paper presents the performance analysis of a blink detector, which detects eye blink, right wink and left wink, under natural & controlled lighting conditions and for variable user distance from the camera. The blink detector has been implemented by using a webcam, a computer and MATLAB software with image processing and computer vision toolbox. It divides the whole process of blink detection into three parts: face and eyes pair localization, blink detection using pixels' motion analysis and classification of blinks as left wink, right wink and eye blink i.e. blinking both eyes simultaneously. The detection accuracy of the detector was measured under natural and controlled lighting conditions for different values of user distance from the camera. Average detection accuracy of the detector under controlled lighting conditions observed to be 96%, 92% and 88% for detection of eye blink, left wink and right wink, respectively. From the overall analysis it has been observed that the system gives significantly better performance under controlled lighting conditions than under natural lighting conditions, and when the user sits at a distance of about 0.5 meter from the camera.

Keywords - real-time eye blink detection, pixels' motion analysis, varying lighting conditions, distance of user from camera, human-computer interaction

I. INTRODUCTION

Eye blink detection plays a very important role in the field of human computer interaction. It is used in the applications like object selection [1], driver drowsiness detection [2], in cameras and smart phones [3], games [4] and wheelchair control [5]. Two widely used methods cited in the literature for measurement of eye blinks are using Electrooculography (EOG) and Videooculography (VOG) [6]. In EOG method, some electrodes are placed around the eyes of a user and the output of these electrodes is refined & blinks are detected by using signal conditioning electronics [7]. In VOG method, a user sits in front of a camera and the computer performs analysis over video frames for blink detection [8]. This method does not require any sensor/electrodes to be placed on the user's face and is hence convenient to use. Videooculography have been set to use in a wide field of technical research applications and is the most discussed topic of research. Two most important parameters which decide the performance of a VOG based blink detector are: environmental lighting conditions [9] and the distance of the user from the camera [10].

Blinks are classified as voluntary and involuntary (automatic) blinks. The blinks performed consciously are called as voluntary eye blinks. It may be simultaneous blinking of both eyes or blinking of one eye at a time. Generally, voluntary and involuntary blinks are distinguished based upon their time duration. Because, in case of involuntary eye blinks an eye closes for about 310±7.3ms [2]. So, to differentiate a voluntary eye blink from involuntary eye blink, its duration should be greater than about 320ms.

Eyes detection methods (using VOG) are classified as direct eyes detection methods and indirect eyes detection methods. In direct eyes detection, eyes are detected directly in the image or a video frame, while in indirect methods; face localization is performed before eyes detection process. Eyes can be directly detected in the input frame without the face detection step, but the two step detection enhances the confidence of eyes detection. Further, eyes detection methods are classified as: active methods and passive methods [11]. Passive eye detectors work on images taken in natural scenes, without any special illumination and therefore can be applied to movies, broadcast news, etc. Active eye-detection methods use special illumination and thus are applicable to real-time situations in controlled environments, such as eye-gaze tracking, iris recognition, and video conferencing [12].

This paper presents an algorithm for detection of eye blinks using video-occulography in both active and passive modes. The blink detector performance has been checked for varying distance of user from the camera under natural and controlled lighting conditions. The paper has been organized as follows: Section I contains the introduction to eye blink detection, Section II explains the methodology of blink detection used in this research followed by results and discussion in Section III. Finally, Section IV concludes the research work presented in this paper.

II. METHODOLOGY

In this paper eye blink is defined as the blink performed by both the eyes simultaneously and eye wink is defined as blinking one eye (left/right) at a time. Here, eye blink/wink detection is performed by using videooculography (VOG) in which a webcam is used to acquire facial images (video frames) of the user and the images are processed by MATLAB software. An overview of the process of eye blink detection is shown in figure 1, in which, the first step is real-time video frame acquisition using a webcam. The Viola-Jones algorithm is applied for face localization in video frames and the face area is coped from the image. Then, the Viola-Jones algorithm is again applied on the cropped face area for eyes pair localization and the eyes area is cropped from the frame. Optical flow technique is then applied to find motion vectors in the eyes pair area by comparing current frame with the reference frame. The motion vectors obtained from optical flow analysis provide the magnitude and direction of each pixel movement in the eyes area.

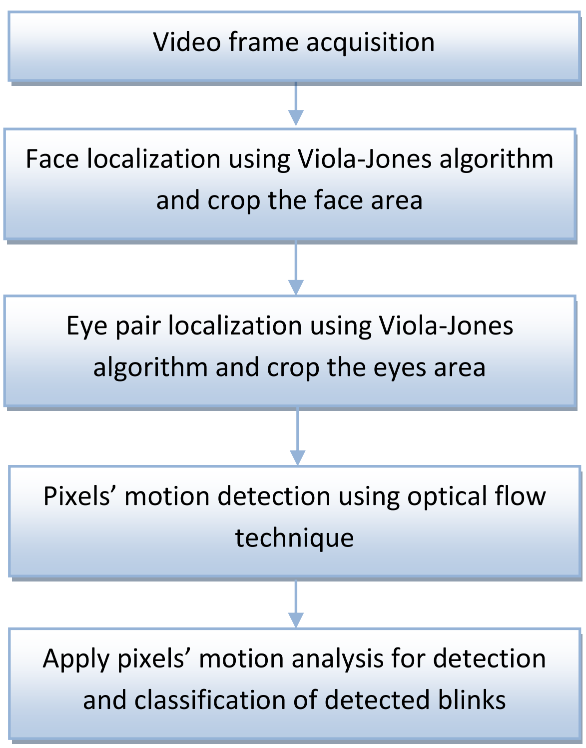
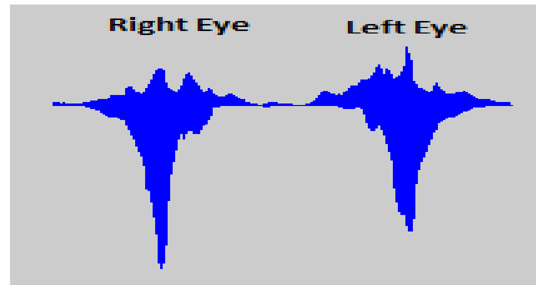
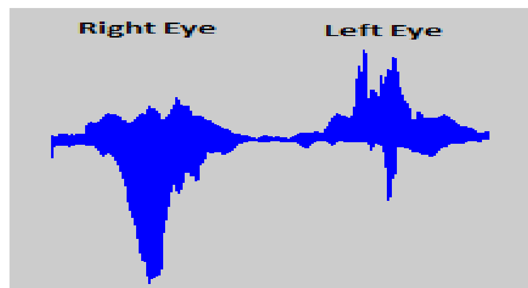


Figure 1. The process of eye blink detection

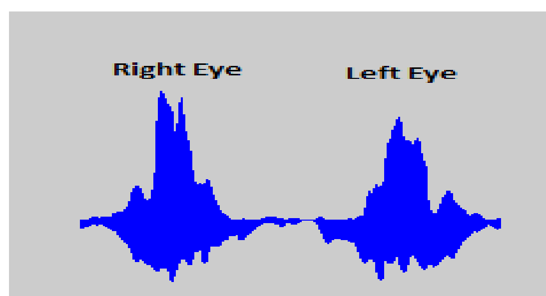
To complete a blink the eyes are closed followed by their opening. During closing of the eyes the majority of the pixels show movement in downward direction. The direction of pixels is shown in upward direction during eyes opening. Further, if one eye is blinked by keeping second eye opened then pixels motion is shown more in the eye area which is performing the wink as compared to the second eye.



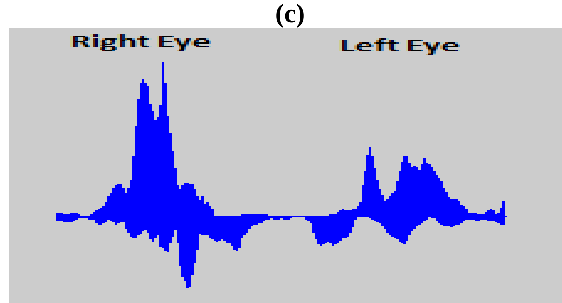
(a)



(b)



(c)



(d)

Figure 2. Sample results of optical flow analysis for (a) open to close both eyes, (b) close to open both eyes, (c) open to close right eye, (d) close to open right eye

Figure 2 shows some sample results for detection of eye blink and right wink in the form of feather plots. Here, it can be seen that during changing eyes position from open to close most of the pixels show downward displacement and the amount of moving pixels is maximum in the eyes area. During close to open movement the majority of the moving pixels show displacement in upward direction. While detection of a wink the magnitude of moving pixels is more in the eye area which is performing the wink as compared to the second eye. Also majority of the pixels show motion in the same direction in which the eye lid is being moved. To confirm a blink the number of pixels in the eye area of magnitude >0.05 should lie in the range (0.25M, 0.75M); and to confirm a wink the range is (0.30M, 0.85M) where M is the total number of pixels in that eye area. Further, the orientation of more than 0.6M and 0.72M pixels should be in the same direction for detection of a blink and wink, respectively.

The designed algorithm was tested on a Windows 7 PC with an Intel Core i3, 2.13 GHz processor, 3 GB RAM and 32 bit OS. Video was captured with an HP Media Smart Webcam at 30 frames/second and 640 × 480 resolution. The program was run on MATLAB R2013a platform with Image Processing and Computer Vision System Toolbox. A fluorescent lamp (8W, 400 lm CFL) was used to project light over user face when the blink detection was performed under controlled lighting conditions. The value of illuminance on the user face was measured by using a Lux meter. The schematic diagram of the blink detection system is shown in figure 3.
The blink detection experiment was performed under two types of lighting conditions (Indoor):

1. Natural lighting conditions
2. Controlled lighting conditions

A camera requires sufficient light to be fallen on the object under detection from an external light source. In natural lighting condition the light falling upon the object depends totally on environmental lighting conditions. In a room if the lighting condition is very poor then the system looses the sensitivity of blink detection. In controlled lighting condition, a CFL is used to project light on the user's face to make the lighting conditions uniform and constant. The monitor also provides a certain amount of illumination on the user's face in any condition.

To check the performance of the blink detector an experiment was performed in which 10 healthy users (7 male and 3 female) ranging in the age from 16 – 43 year (mean 32, SD = 9.0185), and those who felt comfortable in performing all types of blinks, voluntarily participated. The experiment was conducted under natural lighting conditions and controlled lighting conditions at user to camera distance ≈ 0.5m. The users were asked to perform voluntary blinks and winks which were detected by the blink detector. The detector generates different sounds while detection of a blink, left wink and right wink as feedback. The detection accuracy of the blink detector was calculated, for detection of blinks and winks, by using the following formula:

$$\text{Detection Accuracy (DA)} = \frac{TP}{TP+FN} \times 100\% \;\ldots\ldots\; (1)\ [13]$$

Where, TP (true positives) – correctly detected voluntary blinks; FP (false positives) – blinks reported as voluntary blinks but they are not; FN (false negatives) – voluntary blinks not detected by the algorithm.

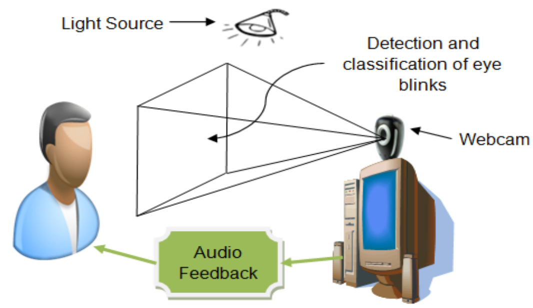


Figure 3. Schematic of the blink detection system

III. RESULTS AND DISCUSSION

In the first phase of the experiment only eye blink detection was performed by three users under controlled lighting conditions (average illuminance ≈ 84 lx) for different values of distance of a user from the camera. This experiment was performed to find the appropriate value of distance of a user from the camera which gives maximum blink detection accuracy. The distance was set as 0.2m, 0.3m, 0.4m, 0.5m, 0.6m, and 0.7m. A graph in figure 4 shows variation of average detection accuracy w. r. t. distance. Here, it can be observed that the optimum value of distance for which the system gives maximum detection accuracy is 0.5 m. So, for the next part of the experiment the distance of a user from the camera screen was kept about 0.5 m.

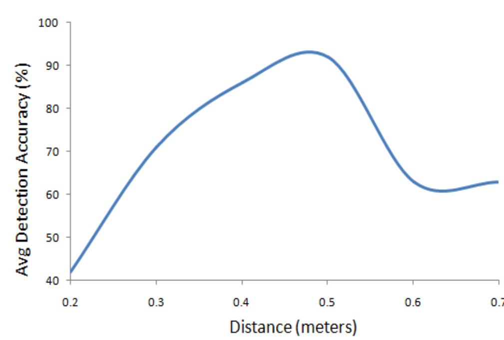


Figure 4 Average blink detection accuracy vs distance of user from the camera under controlled lighting conditions

The second phase of the experiment was performed under controlled as well as natural lighting conditions in which all the 10 users participated. In this part of the experiment a user performed 25 voluntary blinks for each category of left wink, right wink and eye blink. When the experiment was performed under controlled lighting conditions the illuminance on the users face was measured by using lux meter and the results are presented in table 1.

The average value of detection accuracies for detection of eye blink and winks are also presented in table 1. In controlled lighting conditions the detector gives an average detection accuracy of 96%, 92% and 88% in performing blink, left wink and right wink, respectively. Whereas under natural lighting conditions the average detection accuracy obtained is only 64%, 52% and 52% for performing blink, left wink and right wink, respectively. Figure 5 shows blink detector accuracy of 10 users for performing all types of blinks under natural and controlled lighting conditions. It can be observed that the blink detector performs well for all users when used under controlled lighting conditions.

Table 1. Detection accuracy of the blink detector under natural and controlled lighting conditions

User	Natural lighting conditions			Controlled lighting conditions			
	Left wink (%)	Right wink (%)	Eye blink (%)	Illuminance (lx)	Left wink (%)	Right wink (%)	Eye Blink (%)
1	44	52	60	80	92	92	96
2	64	56	72	83	100	96	100
3	52	52	56	90	76	76	92
4	56	44	72	88	96	92	96
5	52	48	60	85	92	80	96
6	56	56	64	81	100	100	100
7	48	56	68	80	96	92	92
8	56	52	60	82	96	92	96
9	40	64	52	87	80	72	92
10	52	40	76	84	92	88	100
Avg Vlaue	**52**	**52**	**64**	**84**	**92**	**88**	**96**

Table 2. Summary of ANOVA output for blink detector performance under controlled and natural lighting conditions

	Eye blink detection	**Left wink detection**	**Right wink detection**
p	5.05×10^{-10}	4.73×10^{-10}	8.12×10^{-9}
F(1,18)	144	145.1613	101.25

A one-way ANOVA was applied for comparison of blink detector performance under controlled and natural lighting conditions and the summary of ANOVA test is given in table 2. For this test the lighting condition was taken as independent variable with two levels (controlled and natural lighting conditions) and detection accuracy was selected as dependent variable. The ANOVA results show that the difference in detection accuracy of the blink detector when used under controlled and natural lighting conditions is very significant ($p<0.001$) for detection of all types of the blinks.

IV. CONCLUSION

The performance analysis of a blink detector under natural and controlled lighting conditions for varying distance of a user from the camera is presented in this paper. The blink detector can detect three types of eye blinks viz eye blink, left wink and right wink using videooculography method which requires a simple webcam, a computer, a CFL and MATLAB software with image processing and computer vision toolbox. From the analysis it is observed that the detector gives significantly better detection accuracy under controlled lighting conditions as compared to natural lighting conditions. In both the lighting conditions the user to camera distance was kept approximately 0.5 m.

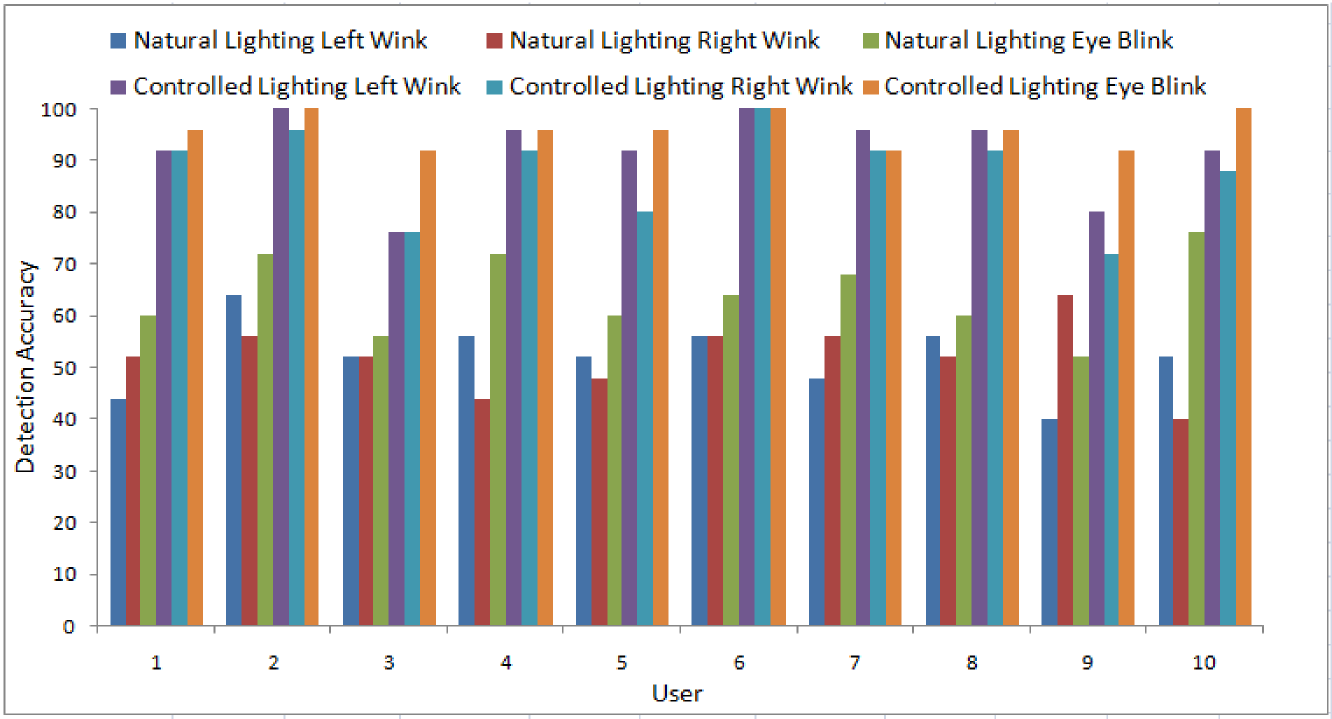


Figure 5. Blink detector accuracy for detection of eye blink, left wink and right wink under controlled and natural lighting conditions

REFERENCES

[1] E. Missimer and M. Betke, "Blink and Wink Detection for Mouse Pointer Control," in *PETRA'10 Proceedings of the 3rd International Conference on Pervasive Technologies Related to Assistive Environments*, 2010.

[2] T. Danisman, I. M. Bilasco, C. Djeraba, and N. Ihaddadene, "Drowsy Driver Detection System using Eye Blink Patterns," in *International Conference on Machine and Web Intelligence*, 2010, pp. 230–233.

[3] E. Miluzzo, T. Wang, and A. T. Campbell, "EyePhone : Activating Mobile Phones With Your Eyes," in *Proceedings of the 2nd ACM SIGCOMM Workshop on Netwroking, Systems and Applications on Mobile Handhelds*, 2010, pp. 15–20.

[4] K. Grauman, M. Betke, J. Lombardi, J. Gips, and G. R. Bradski, "Communication via Eye Blinks and Eyebrow Raises : Video-based Human-Computer Interfaces," *Universal Access in the Information Society*, vol. 2, no. 4, pp. 359–373, 2003.

[5] M. Hashimoto, K. Takahashi, and M. Shimada, "Wheelchair Control Using an EOG- and EMG-Based Gesture Interface," in *IEEE/ASME International Conference on Advanced Intelligent Machatronics*, 2009, pp. 1212–1217.

[6] S. S. Deepika and G. Murugesan, "A Novel Approach for Human Computer Interface on Eye Movements for Disabled People," in *2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT 2015)*, 2015.

[7] Y. Chen and W. S. Newman, "A Human-Robot Interface Based on Electrooculography," in *Proceedings of the 2004 IEEE International Conference on Robotics and Automation*, 2004, pp. 243–248.

[8] T. Pallejà, E. Rubión, M. Tresanchez, and A. Fernández, "Using the Optical Flow to Implement a Relative Virtual Mouse Controlled by Head Movements," *Journal of Universal Computer Science*, vol. 14, no. 19, pp. 3127–3141, 2008.

[9] T. Rajpathak, R. Kumar, and E. Schwartz, "Eye Detection Using Morphological and Color Image Processing," in *2009 Florida Conference on Recent Advances in Robotics, FCRAR 2009*, pp. 1–6.

[10] H. Drewes and A. Schmidt, "Interacting with the Computer using Gaze Gestures," in *INTERACT'07 Proceedings of the 11th IFIP TC 13 International Conference on Human Computer Interaction (Part-II)*, 2007, pp. 475–488.

[11] A. Krolak and P. Strumillo, "Eye-Blink Detection System for Human-Computer Interaction," *Universal Access in the Information Society*, vol. 11, no. 4, pp. 409–419, 2012.

[12] P. Wang, M. B. Green, and Q. Ji, "Automatic Eye Detection

and Its Validation," in *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 2005.

[13] A. A. Mohammed and S. A. Anwer, "Efficient Eye Blink Detection Method for Disabled- Helping Domain," *International Journal of Advanced Computer Science and Applications*, vol. 5, no. 5, pp. 202–206, 2014.

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