Low Cost Robust Blink Detection System

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***Abstract*— Human- Computer Interaction (HCI) systems are designed for disabled people who are unable to move or control any parts of their bodies except for their eyes. The idea behind our proposed system is detecting eye blink feature from a video with a high degree of accuracy. Our proposed system is considered as an alternative input modality enables people with severe disabilities form communicate with the computer. Our proposed system uses Viola Jones to detect the face and eye regions. Our proposed system is based on two steps for determining the state of the eye (being open or closed): The first step is splitting the eye region horizontally into two equal parts. Then find the difference between the number of black pixels of the first horizontal part in eye region and the number of black pixels of the second horizontal part in the eye region. The second step is applied only in the first horizontal part of the eye region by finding the ratio of black pixels to white pixels in this part, and this step added to ensure accurate results.**

The experimental results have proven that the proposed system detection accuracy is very efficient on the recorded cam videos and accurately detects eye blinks without any restriction on the background. The proposed system is very easy to configure and use. It is totally non-intrusive and it only requires one low-cost web camera and computer.

***Keywords*—Human Computer Interaction, Face Detection, Eye Detection, Blink Detection.**

I. INTRODUCTION

Eye is one of the most salient features of the human face. Eye has a wide range of usage in computer science area, especially in human-computer interaction (HCI) [1]. Eye is one of the most expressive features of the human body for non-verbal, implicit communication. Eye is considered as a rich source for gathering information in our everyday lives. For the previous reasons the eyes play an important role in a large area of consumer-oriented applications like facial expression analysis, computer animation, driver awareness systems, film and advertising industry, or assisting people with a disability with eye-based communication interface [2].

Applications based on eye-blink detection have increased because it is suitable for people who are either normal or disabled (that only can blink their eyes). Eye blinks are the rapid closing and opening of the eyelid. Determining eye status (i.e. Open or closed) is more difficult than just determining eye locations, because of their small region occupancies on the face information or weak contrast between the eye and the surrounding skin [2].It is essential for eye-blink systems to be robust and non-intrusive.

Nowadays, the most commercial eye tracking systems depend on the infrared (IR) light that give a robust and an accurate result. But the use of IR light introduces some drawbacks like: first, most users are not able to get a successful calibration result due to false reflections from glasses, interference with the ambient light, or occlusion by eyelids or eyelashes. It would get worse in some situations, such as the users wearing glasses or the ambient light in an outdoor environment. So, most current eye tracking systems can only work in indoor scenario. Second other users may feel uncomfortable and their eyes tend to dry out as the result of long-time direct exposure to the IR light. Finally the use of IR source and an IR camera increases the cost such that the price of current IR-based commercial systems are very expensive [1].

Recently, different eye tracking systems without IR lights have also been proposed. Our proposed system falls under the second type. Our proposed system introduces an eye-blink system that is based on human visual characteristics. Our proposed system using a low-cost webcam (Only My Laptop Webcam) without IR-light to obtain the frontal face of the user. Comparing the proposed approach with the state-of-art eye tracking methods based on IR-light shows that our proposed system is very simple and very low cost system.

This paper is organized as follows: section II covers the related work. Section III describes the proposed method. Experimental results are shown on section IV. Finally section V presents the conclusion and future studies.

II. RELATED WORK

In previous research on vision-based blink detection, as in [3], [4], [5] and [6] the blink detection system built on finding the difference between successive images (that means the result of the current image depends on the previous one). The limitation of the previous methods is that head movement is not allowed, which is a serious disadvantage for actual blink-based applications. To overcome this limitation, many studies have proposed like Morris et al. [7] Who proposed the eye blink detection method using spatio-temporal filtering and Lucas-Kanade feature tracking to locate the position of the head and to extract eyelid movements, they report good blink detection result (95% true position), but head movements affect the variance map computation and cause a sharp drop in performance.

Sirohey et al [8] presented an approach for determining eye blinks by locating eye corners, eyelids and irises in each frame of an image sequence , and analyzing their movements to determine changes in gaze direction and blinking, respectively. Motion information is estimated using normal flow. And determining the head-independent motions of the irises and eyelids by stabilizing for the head motion . The authors claim their algorithm can track iris and eyelid motion more that 90% of the time, but not in real time.

Grauman et al. [9] Proposed a Blink Link that depends on the changing appearance of the eye throughout a blink.

Chau et al. [10] Proposed a blink detection system based on real time eye tracking with USB camera using the template matching for detecting eyes and analyzing blinks. They report 95% overall blink detection accuracy. The main benefit of such template-based approach is its low computational complexity. The downside is that it only distinguishes between two eye states, open and closed. Any movement in-between is not well defined.

And recently, Heishman et al. [11] implemented the finite state machine (FSM) for calculating eye-blink states.

In another study, Pan et al. [12] used a boosted classifier modelled by an HMM to detect the eye-blink rate. Their method operates in real-time on 320 × 240 webcam images, detecting more than 96% of eye blinks.

Orozco et al. [13] proposed using two appearances-based trackers: the first one tracks iris movements while the second one focuses on eyelids and blinking. Using low resolution input video and a simple appearance model, the method reportedly runs in real-time, achieving good tracking results. Authors didn't try to detect eye blinks; however the method could be used for this purpose.

Bacivarov et al. [14] proposed a straightforward proof-of-concept model, having as an advantage that it models properly the eye region for both eyes open and closed by using AAM-based techniques and it can be adapted to work in real-time. An eye tracker and blink detector were also developed using this model.

Divijak et al. [15] works with recorded video taken by web camera, processes the frames and detects hazardous behavior based on user's eye dynamics and blink patterns. His system builds on template-based method. The experimental results show that system capable of detecting common cases of fatigue behavior with performance more than 95%.

Lee et al. [16] developed a new method for blink detection, which maintains its accuracy even if the facial pose changes, which depends on four steps. First, the face and eye regions are detected by using both the Ada Boost face detector and the Lucas–Kanade–Tomasi (LKT) based method in order to be robust to the facial pose. Secondly, the eye "open" and "closed" states are determined on the basis of two features: the ratio of height to width of the eye region in a still image, and the cumulative difference in the number of black pixels seen in the eye region using an adaptive threshold in successive images. Thirdly, the accuracy of determining the eye state when it is open or closed is increased by combining the above two features on the basis of the support vector machine (SVM). Finally, the SVM classifier for determining the eye state is adaptively selected according to the facial rotation. The performance of eye-blink detection of this method up to 96%.

Naveed et al. [17] this paper presents an efficient eye tracking system having a feature of eye blink detection for controlling an interface. The proposed system is able to track eye movements efficiently and accurately by using the pupil portion and can accurately detect eye blinks whether voluntary and involuntary. The system can track eye portion with the 90% detection accuracy. The system is expanded to work in real time using recorded videos.

III. Proposed Method

In this paper new method to detect the eye state (open or closed) is proposed as shown in Fig.1.

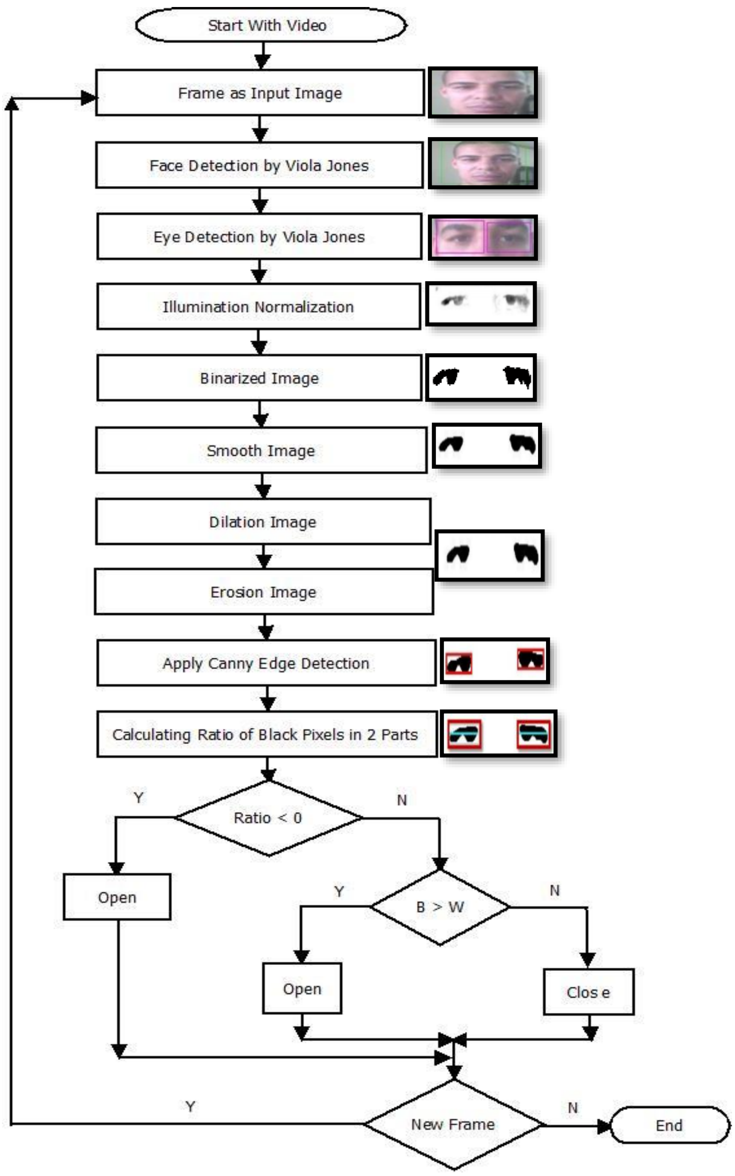

Fig. 1 Flow chart for eye blinks detection process

The proposed algorithm that is used for detecting and analyzing blinks of an eye consists of ten different steps are described in more details in Fig.2.

Our Proposed Algorithm for Analyzing Blinks

Step1	Capture video and Divide it to sequence of frames,
Step2	Detect the face region at each frame (an RGB color image) by using the Viola Jones algorithm,
Step3	Detect the eye region from the detected face region, by using the Viola Jones algorithm,
Step4	Illumination normalization and Binarization of the detected eye region,
Step5	Apply the morphological operation in eye region,
Step6	Compute the difference of the number of black pixels in the first horizontal part of the eye region to the number of black pixels in the second horizontal part of the same eye region,

Step7	IF step6 give a negative value to differentiate , then
	Image Open.
	ELSE
	Start step8.
	END

Step8	Compute the ratio of black pixels to white pixels in the first horizontal part,

Step9	IF step8 true , then
	Image Open.
	ELSE
	Image Closed.

Step10	Repeat the same steps from 1:9 on all frames in capturing video until video frames finished.

Fig. 2 Proposed algorithm

As shown in Fig.2 the first four steps apply the process of detecting faces and eye region. Steps from 6 till 10 of algorithm are used to determine the state of the eye (open or closed), but before that we need to apply some pre-processing on each frame in video as in step 5, the following equation explains the process that is applied to the image in step5:

Result_ Image = (CED (E (D (SF (BI (LC (RF (EyeRegion_Image))))))).

All abbreviations used in the above equation are described in table1.

TABLE I
DESCRIPTION OF OPERATIONS

Symbols	Description
RF	Read Input Image = Eye Region that extracted from the frame.
LC	Lab Conversion.
BI	Binary Image.
SF	Smoothing Filter.
D	Dilate Binary Image.
E	Erosion Dilate Image.
CED	Canny Edge Detector.

Each step mentioned in the proposed algorithm will be explained in details below:

A. *Face Detection*:

In the proposed system Viola Jones algorithm is applied for face detection and tracking as shown in Fig. 3. The Viola Jones algorithm is more efficient for tracking than the AdaBoost Algorithm when working with multiple image frames. Viola Jones can detect more than face if the image contains multi faces. Viola Jones can track different types of facial views, not only the front view like AdaBoost that needs to a Lucas–Kanade–Tomasi (LKT) based method to support non-frontal faces. The basic idea of Viola Jones algorithm is to slide a window across the image and evaluate a face model at every location. Viola Jones algorithm is characterized by being extremely fast and achieving high detection rates.

Fig. 3 Face detection by viola Jones Algorithm

B. *Eye-Region Extraction:*

After detecting the human face, the eye region is also detected by Viola Jones algorithm as shown in Fig.4.

Fig. 4 Eye detection by viola Jones Algorithm

Our proposed system will focus only on eye region. So, we need to extract the eye region .The eye region is extracted from the human face by discarding the lips , nose and other unwanted regions of the face as shown in Fig. 5.

Fig. 5 Extract eye part

Our proposed system is started by extracting the eye region that consists of the eyebrows, the eyelid, eyelashes, pupil, and iris. But, appeared some mistakenly results in the classification step that some closed eyes are classified as open ones. So, we decided to discard eyebrows from eye region. By simply dividing the eye region into three horizontal parts and extracting the first horizontal part of this eye region to segment the eyebrows, as shown in Fig.6, because the existence of this part make conflict in results.

Fig. 6 Final eye part after extracting eyebrows

Using eye region as in Fig. 6 improves the result and decreases error rate.

C. Illumination-Normalization and Binarization of The Detected Eye Region:

The process of determining the eye state (open or closed) firstly needs to binarized image, but the most significant problem that facing image binarization is the effect of lighting variations in imagery. The variation in the lighting increases the noise rate in image. Fig. 7 shows an example of a binarized eye image having an illuminative variation. As shown in Fig. 7 (a) the threshold determined by 40 right eye disappeared and the left eye is clearly displayed. And if we increase the threshold to 55 to enhance the visibility of the left eye the right eye will distort as shown in Fig.7 (b).

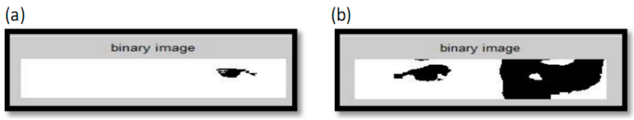

Fig. 7 Binarized images

So, to solve this problem we apply illumination-normalization on the detected eye region by using a Lee algorithm [16] which converts the RGB input image to an L*a*b* image. An illuminative component is acquired by applying a 31×31 median filter to the L image, as shown in Fig. 8(b). Then invert the illuminative image that was obtained, as shown in Fig. 8 (c). After that add the inverted image to the original L image, as shown in Fig. 8 (d).

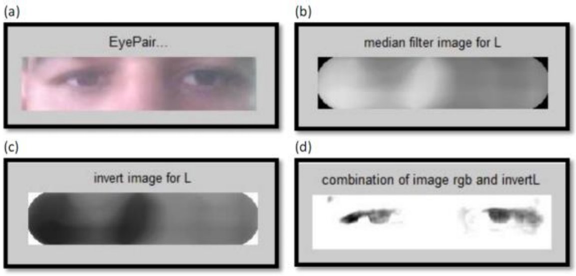

Fig. 8 Image obtained by applying illumination process

We selected this algorithm for the illumination process especially because it is fast and not time-consuming.

After illumination normalization we binarized eye image by applying Otsu threshold on the resulting image of Fig.8 (d) as shown in Fig.9. After trying and testing other kinds of thresholding, we preferred Otsu threshold because the local thresholding or local adaptive binarization methods not effective with these kinds of image which have a low resolution.

Fig. 9 Binarized images by Otsu threshold

D. The Morphological Operation on the Detected Eye Region:

After binarizing the eye region determining the eye state (closed or open) is still a challenge problem because some open eyes are classified as closed ones. So, to overcome this problem, some processes are applied on the binary image before the step of classification starts by smoothing the image by applying average filter on binary image, as shown in Fig.10 (a) then applying dilation and erosion filters, respectively, as shown in Fig.10 (b). Finally Canny edge detector is applied to the resulted image to detect exactly the two eyes as in fig. 10 (c).

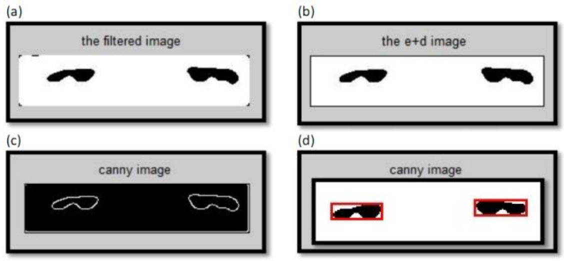

Fig.10. Image after morphological operations

E. The Difference between the Number of Black Pixels in Two Parts of Eye Region:

In order to determine if the eye is open or closed, we received two canny eye objects from the previous step one for the left eye and the second from the right eye as shown in Fig.10(d) We divide each eye object (left and right) horizontally into two equal parts. And for each eye object finding the difference between the number of black pixels in the bottom part of the eye object to the number of black pixels in the above part, and if the difference is greater than zero this means that the eye is closed otherwise the eye is open, as shown in Fig. 11.

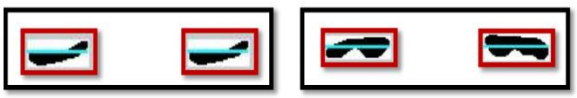

Fig. 11 Eye object divided horizontally into two parts

F. Compute Ratio of Black Pixels to White Pixels in the Above Part:

To enhance the accuracy of determination of an opened or closed eye, we add this step as a final step in the proposed algorithm.

Through our work we found some images with special case, these images are open images but with difference greater than zero. So, our system will classify these images as closed images to avoid this mistake we add this extra step that tests the images with difference greater than zero if they are open or closed. At this step our work is concentrated on the upper part of eye object only .We compute the ratio of black pixels to white pixels in the above part of the eye as shown in Fig.12 , if the number of black pixels is greater than that of white pixels this means that the eye is opened otherwise it is closed.

Fig. 12 Example of the above part of close and open eye

IV. EXPERIMENTAL RESULTS

The System is developed by MATLAB. The reason for choosing MATLAB is that it has powerful graphics and ease of use. MATLAB R2012a is a version that we have chosen for designing and implementation. This implementation is tested on Windows 7 32bit operating system with an Intel® core2™ Duo CPU(2.20GHz) and 3GB of RAM. The camera in our system is HP WebCam101 that built in camera embedded in the used laptop.

For the performance evaluation of the proposed method, we used five different databases. The first two databases are our own database, which are captured from laptop webcam and the spatial resolution is 640×480 pixels, for different people their ages between 25 and 35, the number of frames in the first video are 120 frames , and the number of frames in the second video are 192 frames. The third database is the Talking Face video database, which contains one video having 999 frames captured from one Caucasian male whose age is estimated as 20s or 30s. It includes 61 blinks in all [18]. The fourth database is downloaded videos from the web, for female with age around 25 year, which contains video having 149 frames. The fifth database is the ZJU Eye blink Database, which comprises 20 short videos having 2950 frames (320 × 240 pixels) captured from 20 Chinese people (13 males and 7 females, dark brown eye colors, ages are estimated as 20s) at a capturing speed of 30 frames/s. They include 255 blinks in all [19].

Table 2 lists the face and eye detection accuracies of our proposed method that used Viola Jones as a detection tool on different databases for frontal face.

TABLE2

THE FACE AND EYE DETECTION ACCURACIES (UNIT : %)

Dataset	Our Own Database	Talking
Face	100%	100%
Eye	95%	100%

In our proposed system we don't begin with a proposed algorithm that in Fig. 2 directly. We began with the first four steps only and stored the results. But the result, which we got was not accurate. So, we tried all steps of the proposed algorithm except steps 5 and 8 with extra step know as step* that computes the ratio of test to level. Ratio means dividing all the white pixels in the eye region by the total number of all pixels in this eye region. And level means the selected threshold for eye region. This modification gave results better that obtained from using the algorithm with steps from step 1 to step 4 only .Finally for more improving to the results we added morphological step to the algorithm and modified the algorithm by substituting step* by steps from step6 till step10 .And the final algorithm became as shown in Fig. 2. At Table 3 we stored the results of algorithm in different stages until it reached to final form:

TABLE3

SOME RESULT FOR TRYING ALGORITHM WITH DIFFERENT DATSETS

Database	Step1:Step4 only	Step1:Step10 without Step5 & step8 and step*	Step1:Step10
Our Own Database1	48%	65%	99%
Our Own Database2	58%	71%	85%
Talking	90%	72%	98%
DB_Girl	80%	90%	99%
ZJU Database	70%	85%	95%

The increasing of the accuracy results gradually by applying the steps of the proposed algorithm are shown in Fig. 13.

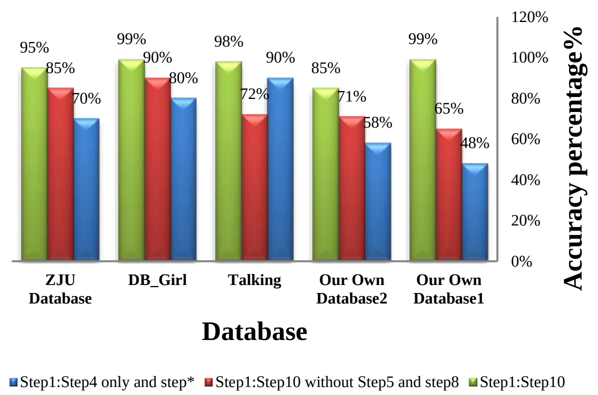

Fig. 13 Accuracy of different databases with algorithm steps

The eye-state Detection performance is measured using two measurement "Recall" and "Precision". Recall: is the average detection rate (DR), which is calculated by the equation (1):

$$\text{Recall} = \frac{\text{TP}}{\text{TP+FN}} \quad (1)$$

Where TP is the number of true positives (implies correct detection of eye-state means open eye returned as open eye) and FN is the number of false negative (closed eye returned as open eye). Precision: is calculated by the equation (2):

$$\text{Precision} = \frac{\text{TP}}{\text{TP+FP}} \quad (2)$$

Where TP is the number of true positives (implies correct detection of eye-state) and FP is the number of false positives (implies an open eye returned as closed eye). As shown in Table4 result of database for recall and precision.

TABLE4

THE RESULT OF RECALL AND PRECISION ON THE VARIOUS DATASETS (UNIT : %)

Database	Recall	Precision
Our Own Database1	94%	100%
Our Own Database2	66%	99%
Talking	96%	96%
DB_Girl	100%	99%
ZJU Database	95%	98%
Average	**90.5%**	**98%**

The average of recall result is 90% and the average of precision result is 98%. From the previous result that appears in table 4 we can compute F-Measure (is the harmonic mean of precision and recall) from the equation (3):

$$\text{F} = 2 * \frac{\text{P}*\text{R}}{\text{P+R}} \quad (3)$$

Where P is the precision and R is the recall. The result of F=2* (8869/188.5) =94.

Examples of all kinds of the databases that we used are shown in Fig. 14. Some cases from used database in the ZJU Database as in Fig. 14 (a). Talking as in Fig. 14 (b). Our own database as in Fig. 14 (c).

Fig. 14 Examples of detecting eye blink on different data sets

V. CONCLUSIONS

An eye blink detection system is introduced in this paper. The proposed algorithm starts by detecting human face. Then the eye region is extracted from the detected face. Finally eye blink is detected using shape measurement and other different steps are used to determine eye state. The proposed algorithm can work under different illumination conditions. The Experimental results show that this new algorithm achieves a satisfied performance for eye blink detection. The final results show that the system accuracy is approximately 98%.

In our future research, we intend to test the proposed system in more varied environments and with facial poses. We also intend to enhance the performance of our blink - detection system to work with people wearing glasses .

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