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Mathematical Approaches to Count Eye Blinking in Video

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Abstract. Eye Blinking is adopted in so many researches, due to these researches a lot of techniques were developed to cover the requirements of that applications. In this paper, a new method was presented to count the number of eye blinking in video, by looking for the upper and lower eyelid points' coordinates UEcoordinate and LEcoordinate based on polynomials curve fitting using five control (interest) points, which are not manually selected by the user as in previous techniques. In proposed method these points are automatically selected by applying multiple techniques of image processing. In this technique, the vertical distance between the coordinates of the Symmetrical points on both eyelids was calculated and stored in a vector in addition to the frame sequence where eye blink occurred. To count the number of eye blinking, a threshold distance was applied on the vertical distance to detect the existing valleys that represented the number of blinking. The algorithm was tested on different eyes stat in recorded video and the result shows the number of blinks was calculated error free.

Key words: eyelids, polynomial curve fitting, morphology operation ,edge detection

INTRODUCTION

Attention to eye detection applications Interestingly increased. Many detection algorithms Are used in many different applications like in psychology helping techniques to contact with the disabled persons, neurology, surveillance techniques to driver fatigue and computer games [1]. The Human–Computer Interface (HCI) is the point of interaction between a user and a computer. The keyboard, mouse and touch-screen are indeed examples of common input devices. All of these tools necessitate control and cannot be used by people with disabilities. As a result, there is a need to develop alternate human-computer communication mechanisms that'd be beneficial for people with motor disabilities and would allow them to participate in the Information Society [2]. Edge-Projection, Luminosity Projection, Chrominance Projection, and Final Projection are the four projections that have been used to identify the eye. Object Detector employs the Viola Jones algorithm. Eyes are discovered and followed with improved pattern matching of the "Between-the-Eyes" pattern. Regarding that, the proper image is chosen from of the captured images depending on distance "Between-the-eyes". Eye detection classified in some approaches by using the following steps [3]:

i) Regression approach: Understanding the task assignment from of the image input to eye destinations minimizes the distance between the expected and actual eye positions.
ii) Bayesian approach: Learn how to make a model of the eye and how to make a model of the non-eye. Create a "eye prospect" using Bayes' principle. Produces formulas around each pixel of the given image, which will be used to extract a prediction.
iii) Discriminative approach: The issue is described as being one of the classifications. A classifier is programmed to provide a positive result for areas around the eye and a negative result in another place.

RELATED WORK

In 2012, Aleksandra Kro´lak & Paweł Strumiłło proposed an eye-blink detection method for human–computer interaction in their work "**Eye-blink detection system for human–computer interaction**" [2].The paper presents a vision-based human–computer interaction. The interface recognizes and analyzes intentional eye blinks as control signals. Haar-like characteristics for automatic face detection, as well as template matching based eye tracking and eye-blink detection, are among the image processing approaches used. Tracking and eye-blink detection, are among the image processing approaches used.

Fitri Utaminingrum and et al. developed in 2017," Image **Processing for Rapidly Eye Detection based on Robust Haar Sliding Window** ", [4] They presented a method based on the haar classifier method for detecting the ocular region of the eye by adjusting the sliding window's direction. It was first put in the center of the image on the facial area by presuming the location of the eyes region in the image's central section.

In 2018 , Tan Boonchuan and et al. proposed in "**Efficient Iris and Eyelids Detection from Facial Sketch Images** "[5] a basic yet effective method for automatically detecting the iris and eyelids in facial sketch images.

In 2019 Kapil Juneja and Chhavi Rana show a model for accurately detecting eye blinks, in their paper " **Structural and Statistical Similarity Measure based Approach for Effective Eye Blink Recognition** "[6] , The model is divided into three stages. In the first stage, frame similarity analysis, background disconnection, spacial, as well as mathematical filters is combined to recognize the effective eye area on distinctive frames. In the second stage, the model recognizes real-time frontal video as input and extracts the appropriate frames and eye-region.

In 2019 **"Pupil Detection Algorithm Based on Feature Extraction for Eye Gaze**", [7], S. Deivanayagi, and et al. collect pupil eye features precisely within different intensities of eye photos, primarily for localization f defined interest objects and how the human is looking. Everything is becoming virtual in this digital era and digital transformation. This study looks at how eye tracking technology may be used to detect and analyze learners' behavior and emotions on an e-learning platform, such as their level of attentiveness and fatigue.

In 2019 Sree Sharmila T. and *et.al* proposed system " **Eye Blink Detection Using Back Ground Subtraction and Gradient-Based Corner Detection for Preventing CVS** "[8] could help regular internet users improve their health habits by dramatically reducing symptoms. The suggested work employs the Viola Jones algorithm for eye detection, background subtraction for eye blink detection, and gradient-based corner identification, and it is able to detect frequent cases of weariness associated with extended computer use by measuring the eye blink rate.

In 2020 Abdullah Arafat Miah and et.al develop in their work [9] "**Drowsiness Detection Using Eye-Blink Pattern and Mean Eye Landmarks'Distance**" a system that uses real-time video surveillance to recognize or identify a driver's drowsiness. They proposed a strategy in their research that combined image processing techniques with machine e-learning techniques.

EYE REGION EXTRACTION

The algorithm's next step is to locate the eye region in an image (frame). The location of the eyes in the face picture is determined using geometrical dependencies that are understood to exist in the human face. The location of the eyes in the face picture is determined by geometrical dependencies that are understood to exist in the human face.

In this proposed approach, we used the Cascade Object Detector System from the Computer Vision Toolbox in Matlab. The shape of a degraded decision tree, or "hierarchy," is the general formula for the selection process (Fig.2). When the first classifier returns a positive result, the second classifier is evaluated, and it is also adjusted for very high detection rates. If the second workbook yields a positive result, the third workbook is triggered, and so on. A negative outcome at any time causes the child window to be rejected immediately. Stages are generated in the correct order using AdaBoost training workbooks, and thresholds are adjusted to minimize false negatives. In algorithm AdaBoost the threshold is set to ensure that training data has a low error rate. In general, a lower threshold leads to higher detection rates as well as a higher rate of false positives [10].

MORPHOLOGICAL OPERATIONS

Morphological Operations is a broad set of image processing operations that process images based on shapes. Because the dilation procedure thickens the object's boundaries, the next stage in segmenting it is to fill the holes.The flood fill technique is most typically used to fill in the gaps in an input image.It basically turns the background pixels to foreground pixels till it touches the object boundaries in binary images, and it makes the intensity level the same in grayscale images, i.e. it transforms the dark portions surrounding by lighter areas to the same level of intensity [11].

YCBCR COLOR SPACE

In YCbCr color space a color described as "intensity" and takes advantage of human eye characteristics. Intensity is more sensitive to our eyes than hue. As the amount of information to be stored is reduced, the intensity can be stored with greater precision [12].

SUGGESTED METHOD STRUCTURE AND IMPLEMENTATION

The suggested technique applied on recorded videos so it implemented off line and can be extended to work on line. (Fig.1) show the block diagram which demonstrate the overall structure of proposed method steps to count number of eye blinking in a video file. These steps are explained briefly in the following articles:

- **Video Acquisition:**

This is the first stage of the algorithm, and it involves getting a previously stored video file of human eye blinking activity.

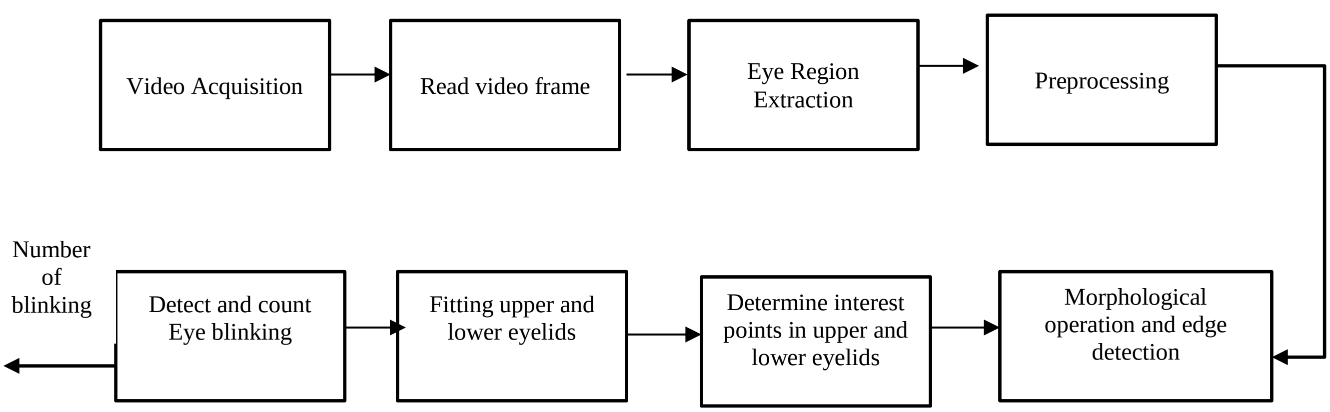


FIGURE1. Block Diagram Of Proposed Algorithm

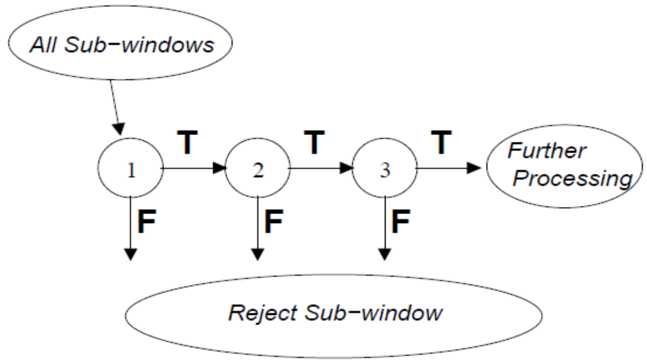


FIGURE 2. Shows Detection Cascade Is Shown Schematically

- **Preprocessing : There are five steps in this stage as illustrated in (Fig.3):**

Step one: Apply flood fill operation to enhance intensity level of the frame.
Step two: Apply histogram equalization to standardize the gray levels values in the frame.
Step three : each frame in video transformed into a color space YCbCr to produce three images (Y(Luminance) , Cr&Cb(Chrominance)).
Step Four: Binarization, Choosing a threshold for transforming the Y image into a binary image is the first step in this process. When the pixel value exceeds threshold, the resulting pixel will have a value of 255 (white) , On the opposite it will be equal to 0 (black) , this procedure aids in the identification of edges in next stage.
Step five: for noise reduction, A median filter with a letter size of 5×5 is used to reduce noise in the frame.

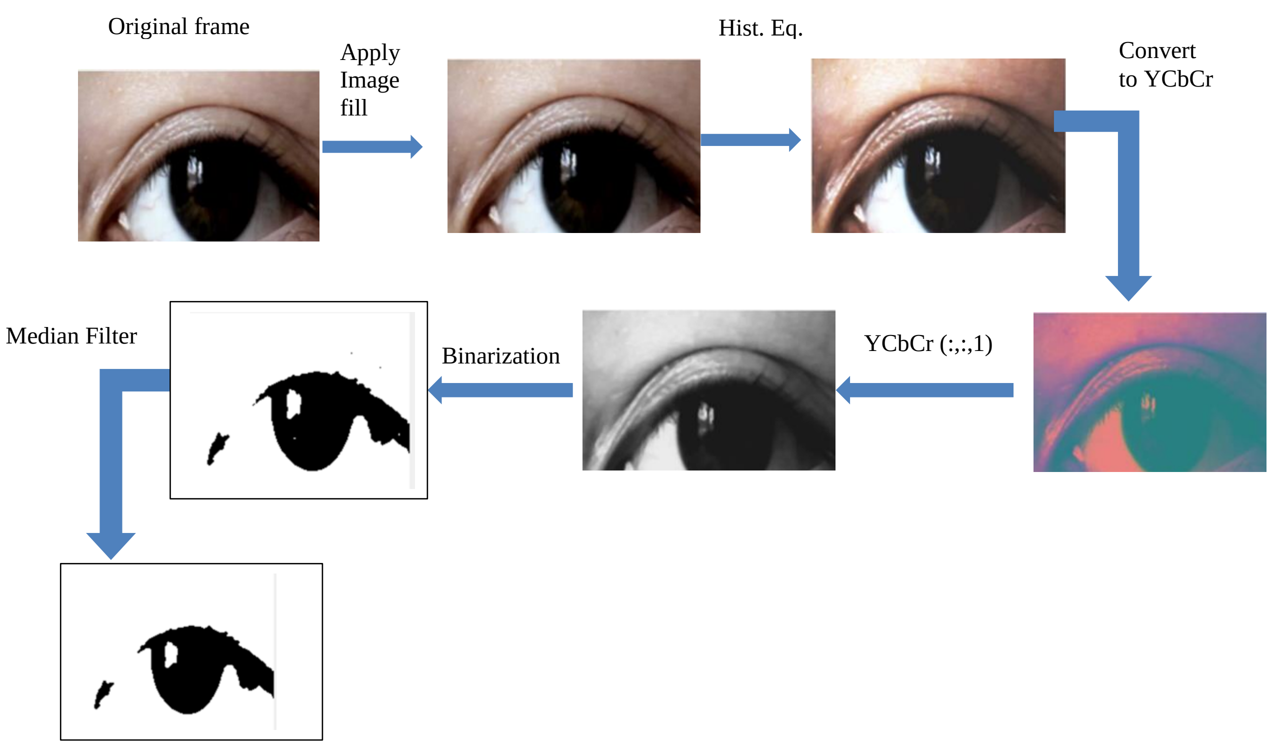


FIGURE 3. Shows The Application Of Preprocessing On One Frame

- **Edge detection :** Two operation needed to achieve final edges :

  First : The magnitude of the gradient is used to introduce first derivatives in image processing. A binary mask image from above stage with the edge detection filter shown in (Fig.4), called the Sobel operator, which can be used to implement Eq. (1) through the mechanics provided in Eq (2). The aim of using a weight value of "2" is to achieve some smoothing by giving the center point more weight. [13].

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

FIGURE4. Sobel Masks

$$\nabla f \approx |(z7 + 2z8 + z9) - (z1 + 2z2 + z3)| + |(z3 + 2z6 + z9) - (z1 + 2z4 + z7)| \quad \ldots (1)$$

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x+s, y+t) \quad \ldots (2)$$

where :
f : image (frame) with size M×N , x=0....M-1 and y= 0....N-1
w: filter mask with size m×n
a= (m-1)/2 , b= (n-1)/2

Second : Find branch points of skeleton by using morphological function in matlab . In the output image the detected edges will be white and the background will be black .

FIGURE5. Demonstrate Edge Detection Stage

- **Determine interest or control points in upper and lower eyelids:**

In the proposed algorithm Control points are not chosen manually by the user, but rather automatically. To describe the curve of the upper eyelid, five control points (see Fig.7) have been identified as follow:

i) Point(x_1,y_1) : To find the point in the far left of binary image, scan the image column by column " from first column to last column " and store the x_1(row index) and y_1(column index) coordinates when a white point is located.

ii)Point(x_2,y_2) : The point on the far right can be identified in the same way as x_1,y_1 except the scanning phase would be from the last column to the first column.

iii) Point(x_3,y_3) : this point found by scanning the binary image, row by row , once a white pixel detected ,save row index as x_3 and y_3 which was calculated as illustrated in Eq.3:

$$y_3 = y_1 + \frac{(y_2 - y_1)}{2} \quad \ldots (3)$$

iv) Point(x_4,y_4) and Point(x_5,y_5) computed from average (or arithmetic mean) of indices of (x_1,y_1) & (x_2,y_2) & (x_3,y_3) as illustrated in Eq.4 ,Eq.5,Eq.6 and Eq.7 ,The average (or arithmetic mean) is the summation value of (n) observations divided by the number of observations [14].

$$x_4 = \frac{(x_1 + x_3)}{2} \quad \dots (4)$$
$$y_4 = \frac{(y_1 + y_3)}{2} \quad \dots (5)$$
$$x_5 = \frac{(x_2 + x_3)}{2} \quad \dots (6)$$
$$y_5 = \frac{(y_2 + y_3)}{2} \quad \dots (7)$$

- **Fitting upper and lower eyelids:**

Curve fitting:

Given a set of (*n+1*) data points, each of pair (x_i, y_i) where I = 0,1,2,..., n, it is necessary to capture the trend in the data points across the entire range by assigning a single function that represents optimal curve. For example, the best straight line (poly. Degree (1)) or the best polynomial 2nd or 3rd degree, and so on. Polynomials and orthogonal functions are two types of curve fitting base functions (x) .Generally polynomial is given by Eq.8 and For a second order polynomial fit in Eq.9 [15].

In the proposed procedure, a polynomial curve fitting was used to evaluate the best fitting second degree polynomial function across previously detected control points, and this polynomial was then used to describe the form of the eyelid contour [16].

$$F(x) = a_0 + a_1x + a_2x^2 + \cdots + a_nx^n \quad \dots (8)$$
$$F(x) = a_0 + a_1x + a_2x^2 \quad \dots (9)$$

the origin coordinate of an image in the top left corner , rows extends from top to down and columns from left to right as shown in (Fig.6) , For this reason we found coefficients for a polynomial p(column) of degree 2 that is a best fit (in a least-squares sense) for the data in x (rows) and polynomial function as shown in Eq.10

$$F(y) = a_0 + a_1y + a_2y^2 \quad \dots (10)$$

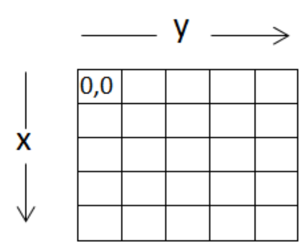


FIGURE 6. Image Axes, X And Y Represent Row Index And Column Index Respectively

After the five points of interest were identified as in (Fig.7) for one of the video frames, and their values were as bellow to find polynomial coefficients (a) , function **polyfit** in matlab has been adopted for this purpose .

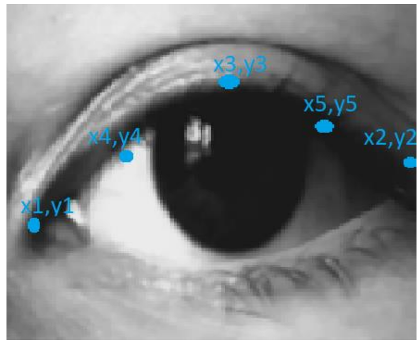
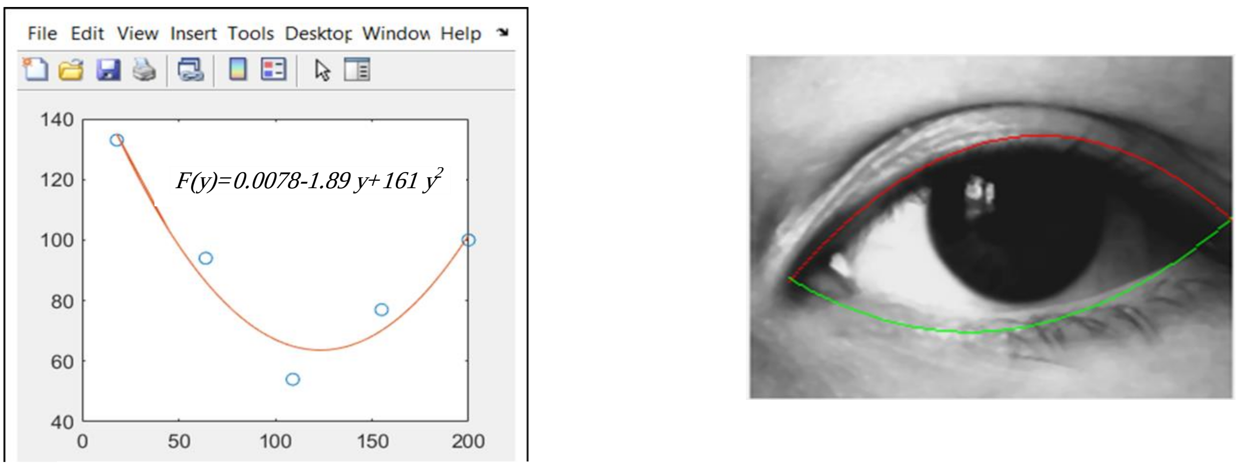


FIGURE7. Interest Points

x=129	93	34	82	64
y=17	200	109	63	154

a =[0.0078 -1.89 161.0] , So, the 2nd degree polynomial fit being as illustrated in (Fig.8)



(a) (b)

FIGURE 8. a) Polynomial Fit b) Eye Image With Upper & Lower Eyelids

Then, for each point in the range between x_1,y_1 (coordinates at the corner of the left eye) and x_2y_2 (coordinates at the corner of the right eye), calculate the polynomial to define the coordinates of points that shape the upper eyelid contour ($UE_{coordinate}$) . In order to obtain ($LE_{coordinate}$) for the lower eyelid, the same steps will be applied to define the upper eyelid. The experiments of the proposed algorithm have shown that polynomials of second degree are adequate to express the general form of both the upper and lower eyelids.

- **Detect and count number of eye blinking**

After determining the coordinates of the points that form the upper and lower eyelids in the previous steps, the following steps are applied:

1. For each frame of video ,calculate the vertical distance (VD) between the X-axis coordinates (rows of the matrix) of the upper eyelid points and the lower eyelid points coordinates as shown in Eq.11:

$$dif_i = \sum_{t=1}^{m} LE_{coordinate\ (t)} - UE_{coordinate(t)} \quad \dots (11)$$

where i=1…………..Number of frames
t=1……..m where m the length of $LE_{coordinate}$

2. Binarize the matrix (*dif*) depending on the threshold (*thrsh*) limit is calculated by the following equation and get *B_dif* as shown in Eq.12:

$$thrsh = \frac{max(dif\ )+min(dif)}{2} \qquad \ldots (12)$$

3. Finds local valley in the data vector for *B_dif* as the number of blinking in a video.

EXPERIMENTAL RESULTS

Matlab 2020 used to implement and test the proposed method on a color video contain from 200 frame each frame size 1080×1920 . The number of blinking counted correctly in proposed method as follow :

After the upper and lower eyelids localization well detected in the previous paragraphs based on polynomial curve fitting as shown in (Fig.8) , the distance between the eyelids for each frame will be shown in (Fig.9):

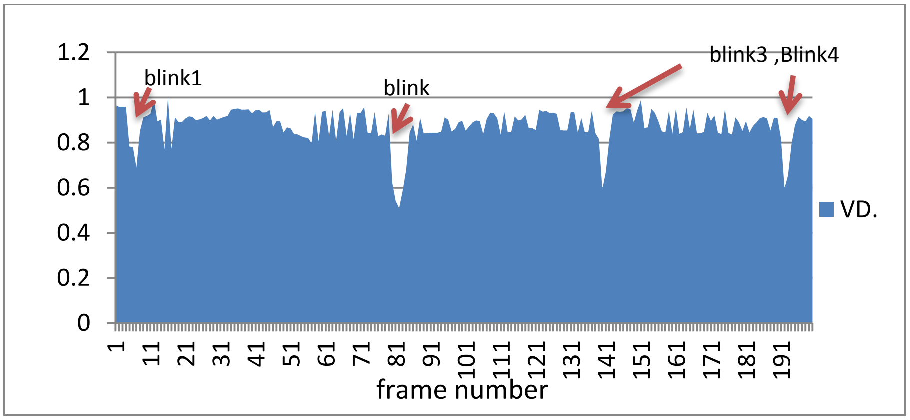


FIGURE 9. Show Vertical Distance Between Eyelids In Video Frames

The significant change in the values of the vertical distances in the above figure shows the existence of an eye blink. Table (1) display the blink occurs through more than one frame (eye opening and closing process) when the algorithm is run, as seen in the following (Fig.10).

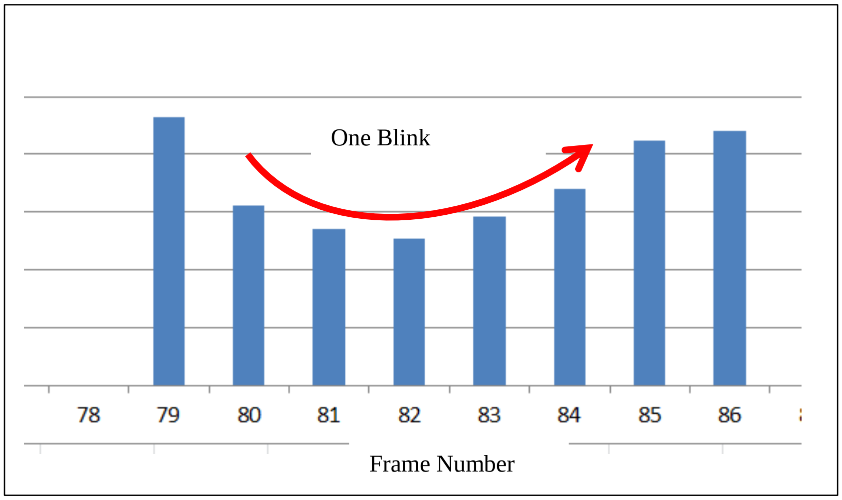


FIGURE10. vertical distance in one blink which occurs through more than one frame

In (Fig.11) show that the distance start decrease when the eye begins the closing process, that mean the upper eyelid approaches from the lower eyelid, and then increases when the eye opens, (i.e. when the upper eyelid moves away from the lower eyelid).

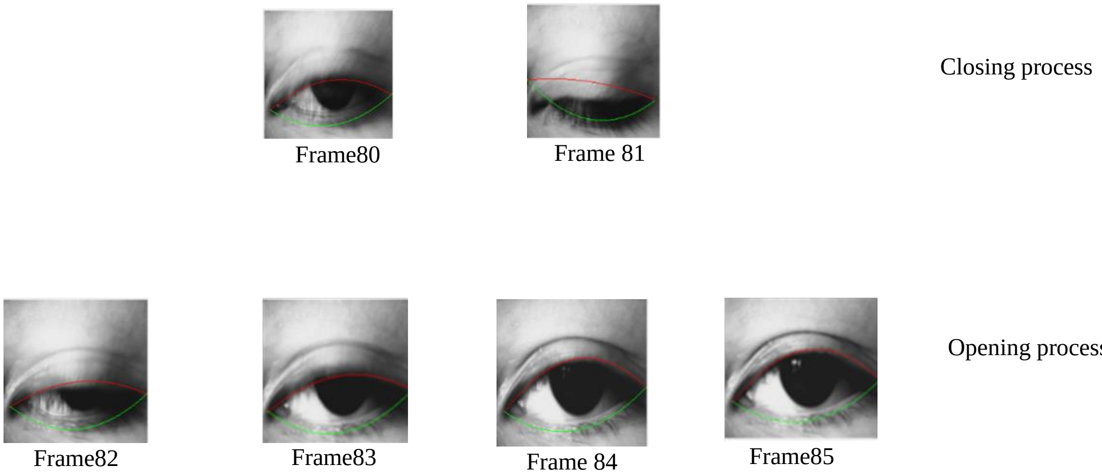


FIGURE11. Shows Frames Through Eye Opening And Closing

TABLE 1. Elucidate The Frames During Which Each Blink Occurred

Blinks	Frames
Blink1	4-8
Blink2	79-85
Blink3	139-143
Blink4	190-195

CONCLUSION

- In this study, a method was developed to find control points with high accuracy by which both the upper and lower eyelids have been automatically detected without need to an operator (human user. The mathematical representation based on polynomial curve fitting give a closed shape to eyelid which is very useful to recognize the eyes stat and decide when it was closed or open, In addition to evaluate the blinking period.
- Implementation of the proposed algorithm on a color video showed that the proposed technique is accurate and have high performance when counting the number of eye's blinking in a video, which was done by measuring the distance between the two eyelid.

FUTURE WORK

As a future work, some stages of the proposed algorithm could be employed to detect other biometric elements such as lips, nose, eyes and etc….

Also this approach can be used for object enhancement specially that contains curves in their boundaries such as eyelids image enhancement.

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