WRITING BASED EYE GAZE ESTIMATION SYSTEM

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ABSTRACT :*Eye-tracking in real-time was developed in the last few years as a challenging problem for computer vision. Hands-free computing is becoming an important area of research as it addresses the needs of quadriplegics This paper presents a Human-computer interaction (HCI) system that is of great importance for amputees and those who have issues with using their hands. The proposed system is an interface that reads the eye movement, in which the eye acts as a computer mouse. This method is based on estimating eye-position and direction (The left, right eye directions). Eye gaze ratio and eye blinking were determined also by calculating the midpoint of middle landmarks of the eye, then the system employs eye movement to write on a virtual keyboard. The proposed system uses a simple webcam and its software requirements. Less than one second was spent on writing the letter by the proposed method using Gaze controlled keyboard which is less time than other related research.*

Keywords – Eye tracking**,** Gaze ratio, eye blinking, landmarks

1. INTRODUCTION

Eye-tracking is a technology that makes it possible for a computer or other device to know where a person is looking. An eye tracker can detect the attention and focus of the user. It allows for unique insights into human behavior and facilitates natural user interfaces in a broad range of devices. The ability to control a computer using the eyes is also vital for people who are unable to speak or use their hands [1]. The study of eye movement emerged from this technique. Common research on eye movement has traditionally centered largely on the fields of behavioral psychology and medicine. In recent years , scientists have recognized the great potential of machine eye movement and combined eye movement with computer vision technology to detect attention. Technology, eye tracking technology, etc... The research of these vision technologies involves optics, computer science, physiology and other fields, including the detection, localization, tracking and other physiological features of human face, human eye and iris. [2]. There are different types of eye tracking device and the most appropriate one for the user depends on the nature of research. The main types are:

- Screen based: These are stand-alone, remote devices that either come as an individual unit or a smaller panel that can be attached to a laptop or monitor.
- Wearable: These include eye-tracking glasses and virtual reality (VR) headsets with integrated eye-tracking.
- Webcam eye trackers do not have sensors or specialized cameras, they are solely comprised of the webcam device attached or built-in to a computer [3], which used in this study.

Webcam eye-tracking requires the built-in or external webcam that is connected to a laptop or computer to collect details on where the user is looking. This approach does not contain rays of infrared light, instead, it relies on the image generated from the webcam. An algorithm is used to get the position of the head and eyes, then the direction of the eyes is correlated to an image on the Webcam eye-tracking requires the built-in or external webcam that is connected to a laptop or computer to collect details on where the user is looking. This approach does not contain rays of infrared light, instead, it relies on the image generated from the webcam. An algorithm is used to get the position of the head and eyes, then the direction of the eyes is correlated to an image on the screen. webcam eye-tracking enables large-scale studies and a fast turnaround which is ideal for quantitative research. the Python language is one of the most suitable programming languages for building an application that depends on eye movement as it contains a library called OpenCv and it's defined as an open-source computer vision and machine learning library. It was built with a vision to provide basic infrastructure to the computer vision application [4]. The process of determining eye directions by OpenCv library is expressed in general as shown in figure 1.

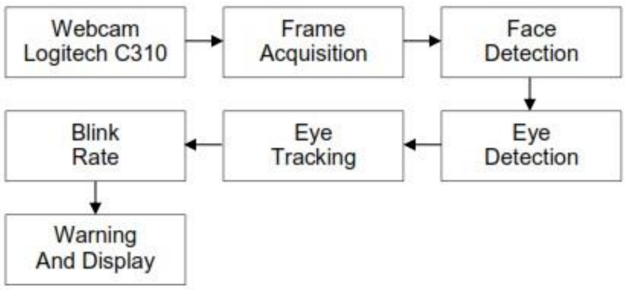

Figure 1: Main steeps for eye tracking

The library has more than 2500 optimized algorithms, which includes a comprehensive set of both classic and state-of-the-art computer vision and machine learning algorithms. These algorithms can be used to detect and recognize faces, track camera movements, follow eye movements, recognize scenery, etc. besides, the applications that are designed using this library are suitable for running on computers and smartphones [5]. The objective of this research is trying to help people who have issues with using their hands in writing-based eye movement using simple webcam. This proposed system does not contain any electronic tools and based on programming only so its cost is very low.

2. LITERATURE SURVEY

The technology which allows extensive use of the principle of eye- tracking includes sectors in the automotive industry, medical science, exhaustion simulation, automobile simulators, cognitive tests, computer vision, behavior recognition, etc. Over a span of time the importance of eye recognition and monitoring in industrial applications grew. This importance of eye-tracking applications leads to more effective and durable designs that are required in many modern appliances. An extensive review of the literature relating to the eye-tracking system has been carried out in the field of healthcare applications.

In [6], a proposed eye tracking system is presented, which based on extracting frame from captured video then the image is converted from the RGB format to a single dimension grayscale. Gamma correction is applied to the image to correct its brightness and contrast. The eye region is detected by using an algorithm is called the Viola-Jones algorithm. The result of the experiment is that the elapsed time of gaze detection is 33.82 second.

The authors in [7] proposed a system starts with a webcam to capture the eye images and send a signal to an electronic circuit is called Raspberry Pi for digital image processing which is based on OpenCV library to detect the 2D motion direction of the eyeball. then the author uses the motion of the eyeball as the cursor control on the Raspberry Pi screen to control some devices such as wheelchair control, electrical device control, and sending a message to the smartphone. The component of the system is the eyeglass connected with webcam and the webcam is connected to a Raspberry Pi microprocessor. The result of the experiment is that the elapsed time of gaze detection is 5.2 s but the cost was very high.

A proposed algorithm, introduced in[8], which performs mouse functions by providing a hands-free interaction between computers and humans. It offers an alternative to the conventional machine with a mouse. By using various expressions of a face using computer vision and matching it with the expression already stored and performing actions as per the step. This algorithm can help visually disabled persons use their face and eye movement to execute the functions of a mouse. It makes it possible for them to left-click, right-click, scroll up and down, move up , down, left, right the cursor. Webcam, NumPy, dlib, and a number of other specific libraries have a very simple need for the framework.

The authors in [9] proposed a nurse call system driven by image processing of user's eye movements. The system composed of a computer, a camera, two light emitting diode (LED) lamps and a speaker is capable of non-contact/non-constraint operation. According to the predetermined particular pattern, a user shifts his or her eyes, then the system extracts from the image certain patterns of eye movements. After detecting those patterns, the system makes a high sound as same as the role of call button at bedside in hospital .A user can always understand the current condition of the system operation as the flashing pattern of two LED lamps during system execution. Using the data reported from normal healthy subjects, the development and evaluation of the algorithm for detecting eye motion patterns from the image was carried out. The Developed prototype system was used in a subject with movement disorders caused from nerve degeneration.

In [10], a proposed system is presented to assist people with mobility impairments by restoring their ability to move effectively and effortlessly without having to depend on others who use an electric, eye-controlled wheelchair. The system was images of eyes of users which were processed to evaluate gaze orientation and the wheelchair was moved accordingly. To achieve such a feat, a robotic With the aid of a series of proximity sensors, wheelchair control will override any decision taken by the gaze assessor and stop its movement immediately, if the measured distance is less than a well-defined safety margin. The algorithm was working with 90% accuracy.

The work in [11] aims to develop an EOG-based virtual keyboard which uses a threshold-based method for detecting eye movements from EOG signals in real time, then categorized as saccades or flashes using a new series of sequences. An average blink marking accuracy of 99.92% and 100.00%, was obtained by the two categorized respectively, indicating that the two eyes' movements can be reliably detected and distinguished in real time using the proposed algorithm. When these technologies were used to interact with the EOG-based asynchronous virtual keyboard, an average typing speed across subjects was achieved from the equivalent of 4.42 characters per minute.

3. PROPOSED SYSTEM ARCHITECTURE

The proposed system consists of very simple components. A webcam used for face image acquisition. Face and Eye detections were performed ,Then Calculating the gaze ratio for detecting the eye direction. Two virtual Keyboard are designed contains all letters and numbers which help users to write letter or number in less than one second and this is a good contribution in the proposed system. One Virtual keyboard was selected depends on the eye direction. Selecting the wanted letter or number depends on detecting the used eye blinking as shown figure 2.

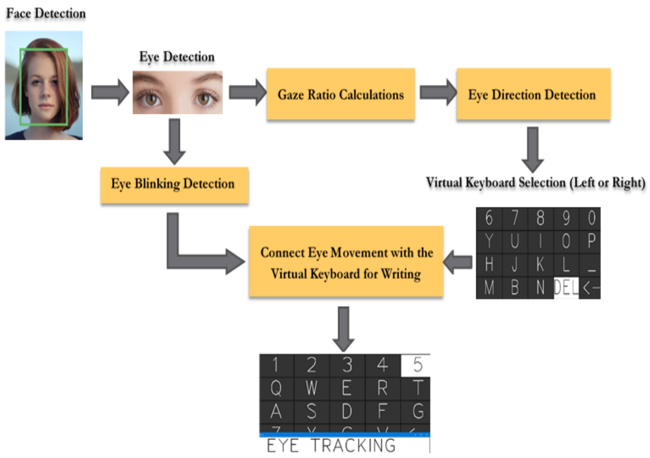

Figure 2: Proposed system architecture

5 adults volunteers aged from 15 to 50 years old used in this study. Participants were comfortably seated in a chair at about 50 cm from the computer screen (PC 17 inches, resolution: 1920×1080, 144-Hz refresh rate, 350 cd/m2).

4. RESULTS OF EXPERIMENT

Eye detection

Performing eye detection after detecting the face from the captured image. The libraries Opencv, Numpy, and also the dlib are used to detect 68 specific facial landmarks points as shown in figure (3).

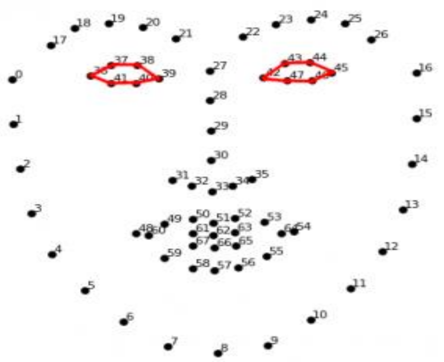

Figure 3: Facial landmarks points

The used algorithms determine the location of the face and the eye according to these landmarks. There is a specific index assigned, to each point. Points of the left eye are (36, 37, 38, 39, 40, 41) and of the right eye are (42, 43, 44, 45, 46, 47).

Eye gaze detection

The main reason for eye-gaze detection is determining the direction of the eye (left-right-center). It is known that the

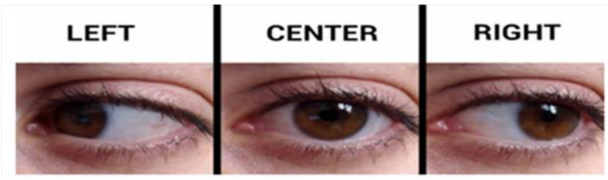

Figure 4: The Eye detection

eye is divided into two parts sclera (white part of the eye) and pupil.

By looking at the image above, it's that the sclera fills the right part of the eye when the eye is looking at the left, The reverse occurs when looking to the right and the white is well balanced between left and right when it looks to the centre. Therefore, we focus to detect the white part(sclera). The idea is to split the eye into two parts and to find out which of the two parts there is more sclera visible. If the sclera is more visible on the right part, so the eye is looking at the left and versa. Technically to detect the sclera the will be converted into grayscale, then finding a threshold value of eye (the value which Separates between sclera and pupil) and counting the white pixels. then get the ratio between left side white pixels and right side white pixels.This ratio represents where the specific eye is looking. Normally both the eyes look in the same direction, so if we correctly detect the gaze of a single eye, we detect the gaze of both eyes.

Calculation of gaze ratio:-

The function divides the eye into two parts, right and left sides. The gaze ratio was calculated by counting the white pixels on each side as the following equation:

$$Gaze\ Ratio = \frac{\text{Left Side White Pixels}}{\text{Right Side White Pixels}} \qquad (1)$$

The Gaze Ratio was calculated for the right and left eyes, Then the final gaze ratio was calculated for both eyes together by this equation:-

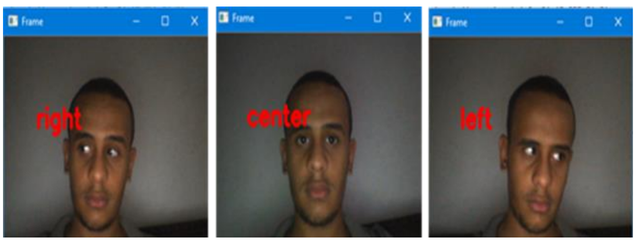

Figure 5: Eye directions using the proposed system

$$Gaze\ Ratio\ for\ both\ eye = \frac{\text{Right Eye Gaze Ratio} + \text{Left Eye Gaze Ratio}}{2} \qquad (2)$$

determine the direction of the eye using the proposed system, all the volunteers were placed in front of the webcam and move their eyes left, right, and in the center. It observed that when the eye direction is to the right, the gaze ratio value is less than 1 and when the eye direction is left, the gaze ratio value is greater than 1.7 and when the eye direction is center, the gaze ratio value is in between 1 and 1.7. as shown in figure 5.

Virtual keyboard

Virtual keyboard was designed to display the Keys on the screen and light them up one at a time. Once the key wanted to press is lighted up, we simply would need to close our eyes then the key will be pressed.

Creating the virtual keyboard

An empty black window is created and called (keyboard) with the size of 1850 pixels of width and 800 pixels of height then the keys are added. Each key is just a rectangle that contains some text. Therefore, the Rectangles are drawn with the number of letters inside the black window. Then the letters are defined inside the rectangles by function contain three parameters the letter index, the letter, and if light up or not in the key. The keyboard is split into two parts (left and right), every part of the keyboard can be accessed by looking in a specific direction.

For example, if all the letters that are on the left sides wanted to be accessed, just look to the left and the left keyboard will be activated. As shown in figure 6 one of two keyboards contain only half of the letters and numbers and considered as left side keyboard and the second keyboard contains all the remaining letters and numbers which considered right side keyboard. The using of two keyboards make the system easier to use and take a shorter time for writing than using one keyboard.

Figure 6: left and right virtual keyboards

The button (<-) means back to main keyboard as shown in figure 10 and the button (_)means space between letters while button (DEL) means delete the letter. The following figure shows the main screen, which is divided into two parts, left and right. When looking to the right, the right keyboard) is opened while when looking to the left, the left keyboard is opened.

Figure 7: The main keyboard

Eye blinking detection

Eye blinking means that the eye is closed, the eye is blinking when:

- The eyelid is closed.
- Eyeball can't be seen .
- Bottom and upper eyelashes connect together.

To calculate the blinking value , Two vertical lines are drawn at each eye as shown in figure 8 .

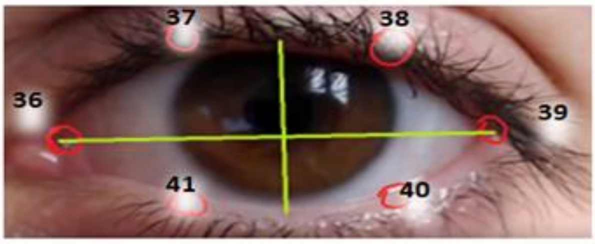

Figure 8: Two lines where eye is open

It is noticed that the size of horizontal lines is almost identical in the closed eye and in the open eye while the vertical line is much longer in the open eye in comparison with the closed eye. In the closed eye, the vertical line almost disappears as shown in figure 9.

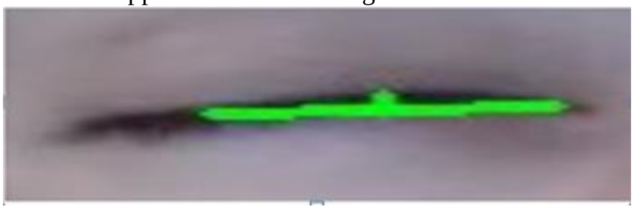

Figure 9: Two lines where eye is closed

The length of the horizontal and vertical lines was used to calculate the blinking ratio as in the following equation:

$$Blinking\ Ratio = \frac{Horizontal\ Line\ Lenght}{Vertical\ Line\ Lenght} \quad (3)$$

The Blinking Ratio was calculated for right and left eyes to get the final Blinking Ratio by this equation:

$$\text{Blinking Ratio for both eyes} = \frac{\text{(Lef Eye Blinking Ratio +Right Eye Blinking Ratio)}}{2} \quad (4)$$

To observe the value of the Blinking Ratio at which the eye is closed, we put the five volunteers in front of the camera and their eyes were closed, and we displayed the value of the Blinking Ratio on screen. We found that the value of it is equal to or greater than 5.7, So if Blinking Ratio is greater than the threshold value which approximately equals 5.7, then the eye is closed. A picture of one of the volunteers is shown in the following figure.

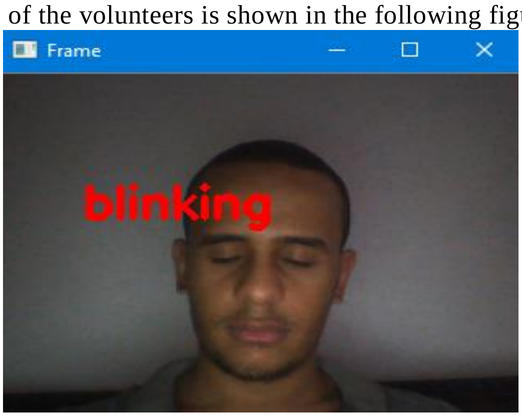

Figure 10: Real time blinking eye

Play sound

Sounds are added to the proposed system. This sound to tell the user when the letter was pressed because when the user is blinking to press the letter, he can't look at the screen at the same time. besides, two other sounds are added one to tell the user when the left keyboard is activated and one to tell when the right one is activated. The library that use to load three sounds is called piglet

Writing in the output window

As explained before, The gaze ratio used to determine the direction of eye movement for selecting the virtual keyboard. These values were appropriate for all volunteers. In The gaze control keyboard, the person waits until the specific key lights up and then close the eyes for less than one second. then the letter appears on the white window "Board" .as shown in figure 14.

Figure 11: **writing in white keyboard**

5. CONCLUSION

Eye tracking is an interesting area of research specially to help disabled for easy communications. For the proposed eye-tracking system, a successful interface between the computer and the webcam was achieved. Eyes landmarks were detected for calculating gaze ratio by tracking of the pupil region of the eye. The experiment setup was built using python, OpenCV. The experimental results show a successful detection and tracking (concerning direction) of the pupil region of the eye, which is serially connected to designed virtual keyboard as a control signal. The concept of eye tracking which presented in this work is used to write using virtual keyboard-based eye movement. Using one virtual keyboard spends many seconds in writing, so in the proposed system, two virtual keyboards (left and right) was designed which takes less than one second in writing letters or number.

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