Eye Click: Eye Gaze based User Interface for the Disabled People

Ghazanfar Latif[1], Muhammad Mohsin Butt[2], Adil Humayun Khan[3]
[1]Information and Computer Science Department
[2]Computer Engineering Department, [3]Electrical Engineering Department
King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia
ghazanfar.latif@nu.edu.pk, engr.mohsin.butt@gmail.com, aadilhk@gmail.com

Abstract— **The disabled people in our society have long been ignored and no significant effort has been made to facilitate them. The aim of our research is to address the issues involved during the interaction of handicapped people with personal computers. The human eye is a very important organ that allows us to sense light and vision involving the minor details of the target object. It allows human beings to have conscious light perception and vision which includes color differentiation and perception of depth. Our research enables disabled individuals to operate mouse or similar pointing devices with the help of eye movements. The technology incorporated in the development of Eye Click software uses an ordinary webcam to detect the eye movements and move the mouse pointer accordingly. To detect the movements, eye is segmented from the user's face and its coordinates are obtained using cross domain algorithm. The pointer automatically moves to the location coordinates obtained from the eye. The user then uses an apparatus through his/her feet for all the 'pointer click' related functions. This will simulate the mouse or other pointing devices. The results of the proposed solution are impressive and beneficial for the people with special needs.**

Keywords- Eye Segmentation, Iris segmentation, Iris localization, Human Computer Interaction, Eye Gaze

I. INTRODUCTION

As per United Nations 2011 report [1] more than 15% of the world's population is living with disabilities and majority of it belongs to South and Middle East Asian countries [2]. In the fast paced world of today, disabled people face limitations in performing many daily life activities that we take for granted [3]. There is a large space between the way disabled people interact with their physical surroundings and the computer world as compared to normal people. As computers are becoming an essential part of daily life, computer skills can significantly improve the living standard of the disabled persons.

Eye click is an innovative revolution that addresses the limitations of the computer user interaction. The software ensures that the world of computing is not one for a limited faction of people, but the wonders of computing are available to all. Eye Click provides an innovative means to the disabled persons to interact with the computer by using their eyes, to move about the screen and perform activities that were not possible earlier. Through the intelligent use of a mere camera and segmenting the eye, tracking eye movement and processing the section of the eye, Eye Click ensures that the disabled can experience the world of computing.

The camera focusing on the eye tracks its movements and shifts the pointer on a screen in the specified direction. This new and revolutionary technique not only helps the less fortunate but also opens up a new dimension in human-computer interaction, where the physical interaction through learned tools and apparatus, is substituted by predictable and natural gestures ensuring efficient and rewarding interaction.

The paper is organized as follows. Section II contains related work carried out in this field and identifies the problems associated with the work of other authors. Section III contains the details of system usability while a detail description of the proposed system and its implementation is described in Section IV. Experimental results are discussed in Section V. In the end, the conclusions and discussions are presented in Section VI.

II. RELATED WORK

The human iris has unique features and patterns that remain stable throughout the life [4]. These features and patterns cannot be changed intentionally as it is the most protected part of the eye [5]. In human eye movement tracking, iris detection and segmentation is the most important task. Daugman [6] proposed iris segmentation algorithm in his work which is thoroughly examined by many researchers. Recently, other algorithms have also been presented to improve the iris segmentation and localization [7] [8] [9] [10] [11]. Emine et al. presented iris segmentation based on a specific texture analysis which uses Haar wavelet [12] in which matching is done using a specific correlation based on the local peaks detection. Hansen discussed different eye detection and tracking techniques based on the photometric and geometric properties, and eye features in [13].

Komogortsev et al. detected eye movements by using Kalman Filter with integrated linear horizontal oculomotor plant mechanical model in [14]. Anatomical features of eye like iris location, muscle location, elasticity, length tension and viscosity were being used to predict eye movements. Use of Eye Gaze in technology plays an important role in human life. Eye gaze tracking technology has a long history but there is very less work done to use the eye tracking as an input for computers [15]. The purpose of our research is to use eye to develop computer interface for the disabled persons.

III. Ease of Use

Using Eye Click, the user simply gazes at a point on the screen where he wants the mouse cursor to be and the webcam detects the location of the eye and moves the cursor to the desired location. The technology incorporated in Eye Click uses an ordinary webcam to detect the eye movements and move the mouse pointer accordingly. Apart from the software a basic webcam and a hardware device that can simulate the left and right click of a mouse are required for this technique. The development of such a hardware device has already been attempted and a successful prototype has been constructed which is discussed in detail in the following sections.

The user looks at the screen where he wants the pointer to move. The attached webcam records the live stream, a new pointer location will be calculated, and the mouse pointer is moved to the new location. Left and right clicks are necessary functions performed by the mouse. For this purpose paddle instead of mouse buttons that can be controlled by the user's feat are used. This method also increases the speed of the mouse operations.

IV. Proposed System

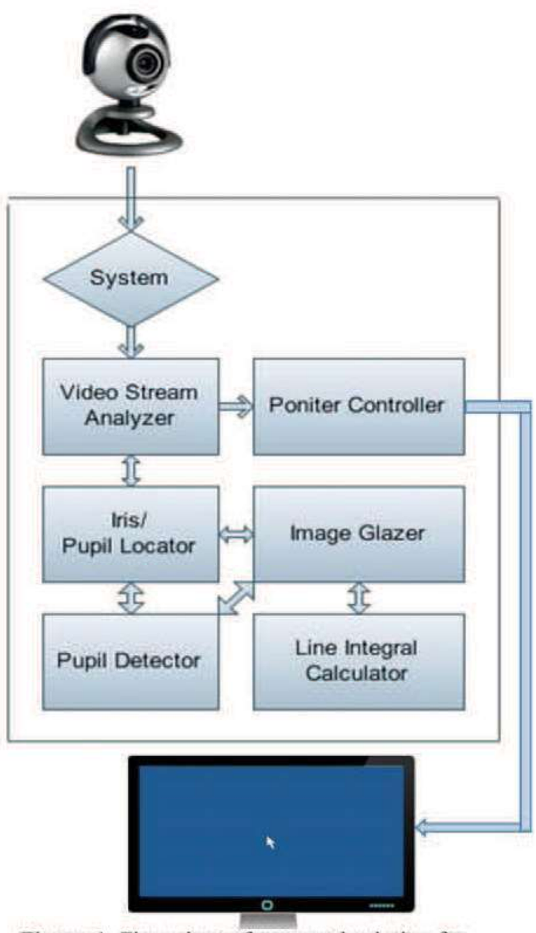

Figure 1. Flow chart of proposed solution for controlling mouse with the help of eye movement

A. Development

There are a few key requirements in our proposed solution. First we need to do the eye segmentation and obtain its coordinates that would be used to map mouse pointer on the screen. Figure 2 and Figure 3 shows the basic model of reference point calculation and detection of the iris of an eye respectively.

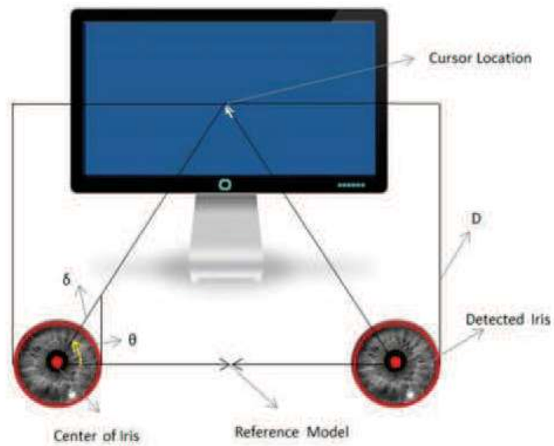

Figure 2. Basic Model of Reference Point calculations

Figure 3. Iris detection, A. Detected iris labeled red, B. Detected Iris from frame with different angle

The second part of our solution is to attach a hardware component that can be used to simulate the mouse clicks. Figure 4 shows the development of the click device that can be used with the help of feet.

B. Required Hardware

The hardware components used in our solution are; a webcam, a simple computer system and a device simulating the mouse clicks. The pointing device is necessary so that the user can "click" objects on the screen; this device can be controlled by one's feet. Figure 5 shows the final implementation of the clicks simulation.

C. Formal Method

First of all, the video stream is captured using a webcam. This stream is broken down into frames and the frame rate is carefully controlled along with its resolution to maximize the efficiency of the algorithm. The image processing/ rendering is dependent on the hardware system (i.e. the CPU and GPU).

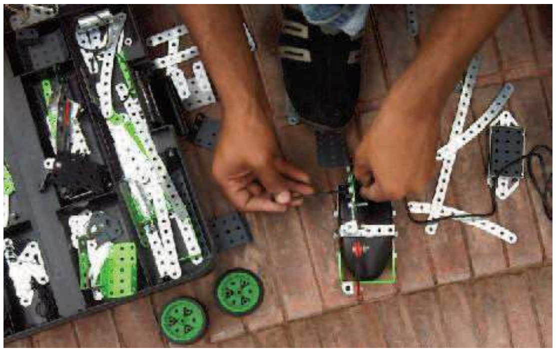

Figure 4. Paddle Click Device Development

Figure 5. Click Device useable with the help of foot

The iris and the pupils of the eye are extracted from the frame captured in the video stream [15]. The coordinates are obtained using the position of the iris and the resolution of the computer system screen; the output is mapped on to the screen. The mapping is done by moving the cursor to the calculated location. The calculation is done according to the coordinates and the screen resolution.

The image is first scaled down to reduce the processing time. Then reflections are removed to the best possible level. This step is necessary because the user may be wearing the glasses. The threshold algorithm is then applied to the image to narrow down the required part of the image [17]. After the necessary precautions to avoid the detection of the eye, the image is smoothened out and the coordinates are obtained using the possible iris location in the smoothed image.

D. Proposed Algorithm

The proposed algorithm consists to the following points.

1. Reduce the image resolution and input the possible minimum and maximum values of the iris.
2. Find the pixel coordinates X, Y of the input image with threshold.
3. For each calculated coordinate, check if X and Y are greater than the minimum iris radius and compare current pixel value with all its surrounding pixels. If the current pixel value is not minimum, then store it in N×N matrix in the place of the X and Y component values.
4. Repeat step 3 and remove the entries that are not local minimum but are present in the N×N matrix.
5. Find the pixel coordinates with maximum smoothness.
6. Repeat step 2 to 5 for traversed image along with Gaussian low pass filter for convolution and store the maximum radius.
7. Find the pixel coordinates using the maximum radius obtained in step 6.
8. To find the normalized line integral vector "L" from the coordinate's radius, the following steps are taken.
   a. Calculate theta θ value from equation (1) where 'n' is the number of polygons.

$$\theta = \frac{2\pi}{n} \quad (1)$$

   b. Find the *X* and *Y* components of the angle by using equation 2 and 3 where C_X is the center of X coordinate and C_Y is the center Y coordinate. The diagonal distance δ is calculated by using equation (4) described in [19].

$$X = C_X \times \sin(\theta) \quad (2)$$

$$Y = C_Y \times \cos(\theta) \quad (3)$$

$$\delta = \sqrt{X^2 + Y^2} \quad (4)$$

   c. For all polygons coordinates, find the pixel values by rounding off X and Y and find line integral by taking average. Equation (5) will be used to find normalized integral of line where $P_{(X,Y)}$ represents pixel value against X and Y coordinates.

$$L = \frac{\sum P_{(X,Y)}}{n} \quad (5)$$

9. Remove all the coordinates with radius 0 from the vector "L".
10. Find the first derivative of all the values in vector "L" and store it in another vector "D".
11. Smooth the 'D' vector by 1-D convolution.
12. Find the maximum value of the smoothness in the above step and the radius on which it was obtained.
13. Modify the coordinates obtained and move the mouse pointer accordingly.

We used the above algorithm to detect and track eye movement in the video or in webcam streaming.

V. Experimental Results

We tested our proposed algorithm for multiple types of inputs like stored video file, images and live stream through camera. The experiments are done using LCD screen with 1280x720 resolutions. The screen is divided in to 64x18 points matrix and sample frames are tested. The modified cross division algorithm results are compared with eye movement tracking proposed in [17] and Geometric based scheme proposed in [18]. Table 1 shows the comparison of experiment results and accuracy.

TABLE 1
EXPERIMENTAL RESULTS

Subject Frame	Original Point	Geometric Based Method	Proposed Cross Domain Method
SF1	1, 32	1, 32	1, 32
SF2	2, 15	2, 15	2, 16
SF3	3, 54	2, 54	3, 54
SF4	4, 37	4, 36	5, 36
SF5	5, 38	6, 40	5, 38
SF6	6, 20	6, 20	6, 21
SF7	7, 50	6, 50	7, 50
SF8	8, 61	8, 60	9 , 62
SF9	9, 62	9, 62	9, 62
SF10	10, 2	8, 2	10, 3
SF11	11, 44	12, 47	11, 44
SF12	12, 29	12, 28	12, 30
SF13	13, 18	12, 14	13, 17
SF14	14, 47	14, 50	14, 47
SF15	15, 31	15, 31	18, 32
SF16	16, 5	17, 6	16, 5
SF17	17, 8	16, 9	17, 10
SF18	18, 41	18, 40	18, 40
Accuracy		**88.30%**	**93.50%**

On the basis of these tests, we calculated the average processing time for the video file and the live stream through webcam. We found that the processing time of eye movement detection from a video file is approximately 0.273 seconds while human eye detection process through webcam takes nearly 0.38 seconds.

VI. Conclusion

The eye gaze based user interface for disable people offers a unique opportunity to interact with computers so they can also benefit from the new technologies in respective fields. The result shows that our proposed solution gave very good performance in terms of eye detection and execution time. The proposed solution will bring a positive change in the life of disabled people; they will be able to operate a computer system without others help.

In this research, though we proposed efficient software for user-computer interaction, there is still room for improvement in clicking hardware device. In future we would like to introduce the pointer clicks based on the eye movements.

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