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Eye Control System Based on Hough Transform Algorithm

Anamika Sonavane, Vibha Gaikwad, Anindita Chowdhury
Department of Computer Engineering
Mumbai University
Thane, India

Abstract—**This paper presents an eye control system that utilizes eye gaze tracking techniques that might be helpful for limb disabled and/or speech impaired people with healthy eyes, to interact with the digital world. We design a motion function as well as an efficient blink detection function where eye gaze position is used to control mouse movement and a blinking action is used to simulate a mouse click. Eye movement is detected through the use of a conventional camera on top of the computer or laptop. Digital Image Processing makes it possible to capture the images of the eye and to detect pupil with the help of Hough Transform algorithm in order to perform the mouse functions accordingly.**

Keywords-eye-gaze position, hough transform, viola-jones algorithm, pupil localization

I. INTRODUCTION

More than 1 billion people in the world have some form of disability. This corresponds to about 15% of the world's population [1]. According to Census 2001, over 21 million people in India are suffering from one or the other kind of disability. This is equivalent to 2.1% of the population [2]. Thus, this much population cannot enjoy the digital world, especially who are limb disabled or speech impaired. A person's eyes convey a great deal of information since, the direction in which an individual is looking shows where his or her attention is focused. Tracking the position of iris can be used to develop user interfaces that allow user to control and manipulate devices in a more natural manner [3].

Research on the visual system, in psychology, in psycholinguistics, marketing and in product design eye trackers are involved as an input device for human-computer interaction. For measuring eye movement, there are a number of methods that are used. The most widely used current designs are video-based eye trackers. In this method a camera focuses on one or both eyes and records eye movement as the viewer looks at some kind of stimulus.

Most modern eye trackers use the center of the pupil and infrared / near-infrared non collimated light, to create corneal reflections (CR), as shown in Fig. 1 and Fig. 2. The vector between the pupil center and the corneal reflections can be used to compute the gaze direction.

A simple calibration procedure of the individual is usually needed before using the eye tracker [4].

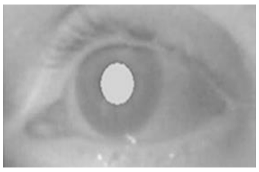

Figure 1. Infrared / near-infrared: bright pupil.

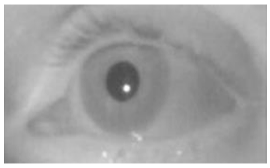

Figure 2. Infrared / near-infrared: dark pupil.

II. EASE OF USE

This paper is structured as follows. Section III states some of the earliest works done, related to eye tracking and ongoing research on the same. Section IV introduces the software and hardware implementation of the eye tracking based input system. Section V illustrates the dependencies that are applicable to the application when being used by user. Finally, a conclusion is drawn in Section VI.

III. PRIOR WORK DONE AND EXPERIMENTS

Eye tracking experiments have an early history. The earliest eye-trackers was designed by Edmund Huey (Huey, 1908), which only consisted of a contact lens like device with a hole for the pupil.

The lens connected to an aluminum pointer, moved in response to the movement of the eye. Huey showed that some words in a sentence are not fixated, by studying and quantifying the regressions. The first non-intrusive eye trackers were built by Guy Thomas Buswell in Chicago, using beams of light that were reflected on the eye and then recording them on film. Buswell made systematic studies into reading and picture viewing. In the 1950s, Alfred L. Yarbus did important eye tracking research and his 1967 book is often quoted. He showed that the task given to a subject has a very large influence on the subject's eye movement. [5]

Eye tracking has found its applications in many projects. Over the past few years, Eye-tracking techniques have been of consider-able interest to the NLP research groups at IIT Bombay [6]. In 2006 a group of Taiwanese engineers developed a "Powered Wheelchair controlled by Eye Tracking system". In order to translate gaze direction into chair movement, they used pupil tracking goggles linked to a computer [7]. After that, in 2011 an Italian group of engineers published a paper that discussed the demerits of eye-controlled electric powered wheelchair (EPW) systems [8]. In 2016, a comparative study of user experience in online-social media branding web pages using eye tracker was conducted [9]. It allows market researchers and brand owners to study the process consumers undertake when viewing and selecting a product. It shows them what elements naturally attracted the most attention and what areas were ignored. Unlike surveys or questionnaires, eye tracking details authentic behavior which is useful when designing advertising, branding, packaging and product placement.

IV. DESIGN OVERVIEW

Eye Tracking is the process of measuring eye-positions and eye-movements of a subject. The devices used in carrying out such experiments are known as eye trackers. Eye trackers can broadly be classified into:

1. Head-mounted eye trackers
2. Remote eye trackers

In head-mounted eye trackers, sensors are embedded into the glasses worn by subjects while in the Remote eye trackers the screen is embedded with sensors for recording eye-movements. A head-mounted eye tracker by Eye Tracker manufacturer Tobii is shown in Fig. 3.

Here, for simplicity here the laptop camera is used to measure the eye movement. The camera captures image frames of eye pupil as input. After the eye is detected it will be processed for calibration. Processing includes conversion to gray-scale followed by canny-edge detection, which will be used to detect pupil center using Hough transform algorithm.

The user can gaze anywhere on the screen and for clicking a button, the user must blink. If the blink duration exceeds 2 seconds, then it will be considered as a click, otherwise not. If the camera is inefficient, then external camera, connected to the computer via USB cable or Bluetooth should be used.

Figure 3. A head-mounted Eye-Tracker from Tobii

A. Hardware Implementation

This system uses a webcam mounted on a laptop or computer. The camera module used has a resolution of 3MP. The laptop used here is Dell Latitude E6510 with a processor (CPU) and with 2 gigahertz (GHz) frequency. The screen resolution is 1024 X 768.

B. Software Implementation

1. Technology Stack :

- Windows Operating System, Windows 7 Professional.
- *Visual Studio 2015 Community version* : Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It is used to develop computer programs, as well as websites, web apps, web services and mobile apps and it supports 36 different programming languages, such as C++, Visual Basic .NET, C, Javascript, Python, Node.js and many more.
- *Open CV with C++* : OpenCV (Open Source Computer Vision) is a library of programming functions mainly aimed at real-time computer vision. OpenCV runs on the following desktop operating systems: Windows, Linux, macOS, FreeBSD, NetBSD, OpenBSD. OpenCV runs on the following mobile operating systems: Android, iOS, Maemo, BlackBerry 10.

2. Working :

The main program includes the preprocessing module, the Viola-Jones algorithm, the Hough transform algorithm, the blink detection method, the coordinate’s transform & calibration method. Fig. 6 illustrates the complete working.

a. Preprocessing: Firstly, the initial image captured from the camera is grayed and is binarized by the preprocessing module.

b. Face and Eye Detection: Face and eye are detected using Viola-Jones algorithm. This algorithm extracts simpler representations of the image and combines those simple representations into more high-level representations in a hierarchical way. This involves extracting properties that are common for a human face, e.g., the nose bridge region is brighter than the eyes or nose looks like a vertical structure with contrast to an eye. Hence, such template features are slide over and are match with the observed face-image, to extract the features, shown in Fig 4. For illustration, we use a blue square to represent the face and green squares to represent eyes.

c. *Iris and Pupil Detection:* In this system, input is provided via the left eye of the user. For this reason, the system utilizes the Hough transform algorithm to detect the

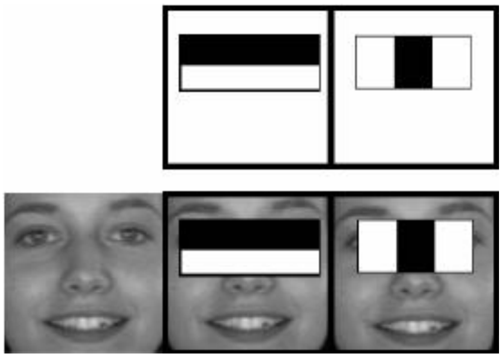

Figure 4. Example of Haar-like features matched with a face-image

pupil center from the initial eye image from the camera.

Theoretically, it's simple to understand the Hough transform algorithm. We are aware that, to fully describe a circle

$$(x - a)^2 + (y - b)^2 = r^2 \quad (1)$$

it is obvious that three unknown parameters (a, b, r) are to be determined. Thus, if at least three points on the same arc are known, we can identify the parameters (a, b, r) by solving

$$\left.\begin{aligned}(x1-a)^2 + (y1-b)^2 = r^2\\ (x2-a)^2 + (y2-b)^2 = r^2\\ (x3-a)^2 + (y3-b)^2 = r^2\end{aligned}\right\} \quad (2)$$

Substituting edge point set (x_n,y_n) into Eq. (2) we can obtain the corresponding parameter set (a_n, b_n), Based on which a best likely parameter set containing the center coordinates and the radius of the circle is estimated by a voting mechanism [10]. The iris is marked with a red circle as shown in Fig. 5. This is followed by the detection of the pupil of the left eye.

d. *Mouse Control:* Once the current center of the pupil is calculated, the difference between the previous center coordinates and the current center coordinates is calculated to determine the change in eye gaze position which is then multiplied with a constant factor, as shown in Eq. (3).

$$\left.\begin{aligned}diff.x = (center.x - lastPoint.x) * 20\\ diff.y = (center.x - lastPoint.y) * -30\end{aligned}\right\} \quad (3)$$

After every change in the gaze position then new coordinates are obtained by adding the difference to the new coordinate.

e. *Blink Detection:* Blink is one of the important behaviors of the proposed system. A common blink detection method involves the template matching method, which uses the eye-closed templates and eye-open templates to match the eye images. The target of the method will be to estimate whether the pupil image has disappeared. If the pupil image disappears, then an event of blink is identified which subsequently performs the clicking function.

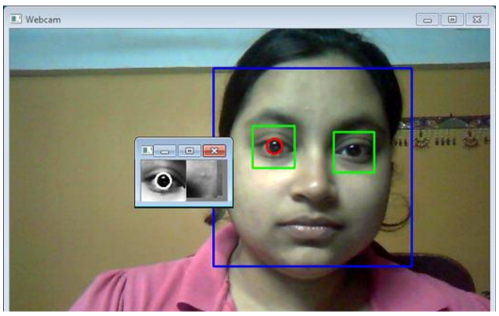

Figure 5. Blue Square represents the face, Green squares represent the eyes and Red circle represents the iris of the left eye (in image), that are detected

C. *User Interface Display Screen*

The display screen for human-computer interaction consists of four equal sized sections, as shown in Fig. 7. For convenience and comfort the dimension of the User Interface is kept approximately equal to that of the laptop screen.

The first section consists of 4 buttons that change colour upon clicking individually. The second section consists of a keyboard containing numbered buttons (from 0 to 9) and

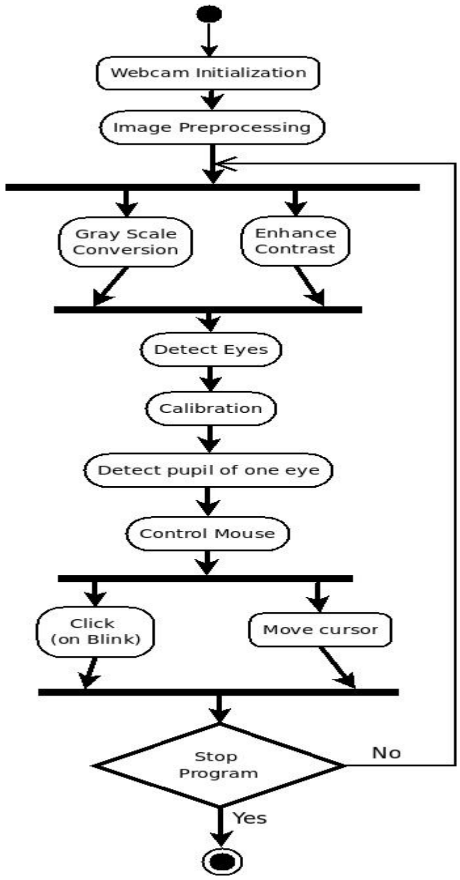

Figure 6. Activity Diagram of the Software

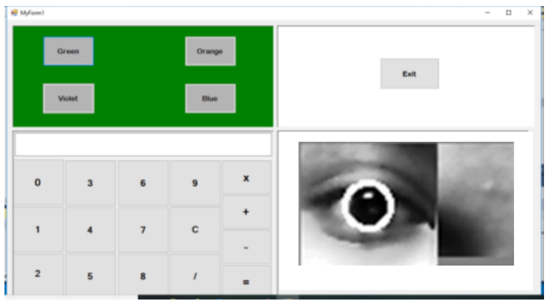

Figure 7. User Interface for human-computer interaction

four fundamental arithmetic buttons (addition, subtraction, multiplication and division) and one cancel button, altogether to act as a calculator. Third section displays the exit button to exit out of the application. And the last section displays the eye image captured at real-time.

V. DEPENDENCIES

A. *Dependency on the distance of the User and the camera:*

The distance between the person and the camera should be as less as possible, preferably 30cm to 35 cm. The reason for this is that, the tracking would not be accurate with large and varying distance.

B. *Dependency on the camera resolution:*

This system is currently being equipped with a 3MP camera. However, camera resolution should be of the best quality, at least 5MP, for higher efficiency of the video captured. It is important in feature extraction that, the image is having good clarity, since different training frames are compared with the obtained image frame for identification of different components.

CONCLUSION AND FUTURE RECOMMENDATIONS

Input through an eye tracking system can be achieved using Hough transform algorithm. The design presented allows control of the mouse through a combination of simple hardware and software components to create an effective system. This system includes a laptop and a webcam. These pieces comprise the hardware. The software includes C++ scripts used to process the data (captured images) and to draw out the mouse movement and click functions.

However, there are several areas of improvement that we discovered during our design process. One of the main anomalies is that the Hough transform performs poorly for detection of non-standard circles. Due to the impact of the camera and eyelashes, most pupils in the pupil images are not perfectly circular. Consequently, the pupil detection of the Hough transform algorithm often makes mistakes. Hence, the next step of our work is:

Firstly, improve the pupil localization method in order to make the coordinates transform more accurate, we can ameliorate the Hough transform algorithm by employing the concept of Purkinje images.

Secondly, with the development of the pupil localization, we increase the number of buttons. In the better version, the system should be used to click any button of the computer system, no matter how small it is.

Thirdly, transplant the system from PC platform to the mobile platform. This can also be made more accurate with the help of a VR gear.

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