Eye Tracking System Based Cursor Control

Submitted in partial fulfillment of the requirements
of the degree of

Bachelor of Engineering
in
Electronics and Telecommunication

by

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2019-20

CERTIFICATE

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This Is To Certify That The Project Entitled "**Eye Tracking System"** Is A Bonafide Work Of **Khan Shah Faisal Niyaz Ahmed (17DET47), Khan Mohd Siddique Naeem (17DET45), Ansari Abdurrahman Mohd Saeed (17DET39), Karbelkar Aysha Faisal (17DET32)** Submitted To The University Of Mumbai In Partial Fulfillment Of The Requirement For The Award Of The Degree Of Bachelor Of Engineering In Department Of Electronics And Telecommunication Engineering.

Supervisor   Examiner

Director   Head of Department

Project Report Approval for Bachelor of Engineering

This project entitled **" Eye Tracking System Based Cursor Control "** by **Khan Shah Faisal Niyaz Ahmed (17DET47), Khan Mohd Siddique Naeem (17DET45), Ansari Abdurrahman Mohd Saeed (17DET39), Karbelkar Aysha Faisal (17DET32)** is approved for the degree of **Bachelor of Engineering in Electronics and Telecommunication**

Examiner

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Supervisor

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Date:

Place:

Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

Large numbers of input devices are available for human interaction with modern computer systems which are operated by hands and a few of them through gestures made using fingers and body movements. The advancements in assistive technology have proposed many concepts for controlling the input and mouse movements by detecting the basic eye movements of a user with the help of the eye tracking systems. We place our focus on the implementation of the computer mouse which is designed to detect the relative position of the cornea with respect to the initially calibrated center and calculate the attributes like angle and speed at which the movement of mouse cursor has to be initiated. The basic Hough man circle detection algorithm is used to process the incoming video frames to detect the cornea which lies in the center of the pupil and the position of the cornea is compared with respect to the calibrated center point with the help of a square grid on which an algorithm is applied to calculate the speed and angle at which the mouse should move with respect to x axis. An innovative method of accessing a computer completely hands-free, is what we intend to present in this paper. The computer shall now be accessible and easily maneuvered through, using merely one's eyes. The paper attempts to present a hands-free method of computer control by adjusting to the individual's pupil movement, simulating the same onto the cursor, and taking inputs that would otherwise be given by a mouse or keyboard that need hands to access. Indeed, one shall not only control a mouse using his eyes, but also access the complete input methodology.

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Keywords And Glossary

Keywords:

MATLAB, Computer Vision Toolbox, Human computer Interaction, Signal Processing, Real-Time system

Glossary:

MATLAB:High performance language for technical computing.

Grayscale image :A image in which the value of each pixel is a single sample only amount light.

Computer vision toolbox: A toolbox in MATLAB that provides algorithms ,functions, and app testing, and video processing systems.

Human Computer Interaction: Interfaces between people and computers.

Signal Processing: Analyzing, modifying and synthesizing signals such as sound, images and biological measurements.

Real-Time system: Here the real time system tends to operate cursor accordingly to the eye movement.

Chapter 1

Introduction

1.1 Background Information

Personal computers were initially used for solving mathematical problems and word processing. In recent years, however, computers have become necessary for every aspect of our daily activities. These activities range from professional applications to personal uses such as internet browsing, shopping, socializing and entertainment. Computers are designed to be readily accessible for normal individuals. However, for individuals with severe physical disabilities such as cerebral palsy or amyotrophic lateral sclerosis, usage of computers is a very challenging task. There have been many research studies on human computer interface (HCI) to improve the interaction between the user and the computer system. Most of these are applicable only to normal individuals. These interfacing methods include a touch sensitive screens, speech recognition methods and many others. Despite the success of these techniques, they were not suitable for the physically disabled individuals. Many researchers have tried to develop methods to help the disabled to interact with computers by using signals such as electroencephalography (EEG) from the brain, facial muscles signals (EMG) and electro-oculogram (EOG). Other methods include limbus, pupil and eye/eyelid tracking , contact lens method, corneal, pupil reflection relationship and head movement measurement. These methods require the use of attachments and electrodes to the head, which makes them impractical. Other high end techniques that are based on infrared tracking of the eye movements to control computers were exceptionally expensive and were not affordable for those who need them.

1.2 Purpose

This document describes the planning, development, and implementation of an Eye Tracking System used to assist people with disabilities and teaching children to learn new languages. The selected hardware, software development, design planning and testing, system integration, and a final implementation design of the Eye Tracking System is detailed within this document.

1.3 Problem Statement

Many people who live with paralysis have a difficult time with day to day tasks. While those with limited use of their limbs may be able to get by, those with full body paralysis have no such luck. Fortunately, most people still retain the ability to use their eyes unhindered. Therefore, tracking eyes has been suggested as a way for paralyzed people to continue interacting with the world. Even children, who are developing social skills or learning a language, interact through sight. If a child has a learning disability, tracking how their eyes react to learning methods allows teachers and researchers to successfully educate children.

Eye tracking is the process of tracing the movement in the eye to give vital information for research purposes. This technology can be applied to studying how pupils react to different situations, language development in children, applications for disabled persons, or detailed robotics and animatronics. Although the use of eye tracking has been seen as a great way to develop new technology, the expensive cost of the equipment that is needed to implement such a device is a major disadvantage. Traditional devices have so far been centered on sophisticated, expensive infrared sources or high resolution cameras.

By developing a simplified and low-cost system, eye tracking devices will become a far more marketable and accessible product to the general public. The focus of the developed system will be away from elaborate hardware of the current eye tracking system, but instead toward clever DSP and other software algorithms.

The method described here is distinctive because unlike existing methods, here there is no use of electrodes, infrared, or any other light source to track the eyes. The only hardware that is required is a PC or laptop along with a webcam, which makes it practical and feasible. By taking consecutive snaps of the user from the camera, the program is designed to process these frames individually at very high speed of processing and compare the iris shift in each frame with respect to the initial frame. The frame undergoes several stages of processing before the eyes can be tracked. After obtaining the processed image, the iris shift is calculated and the program prompts the cursor on the screen to move to the respective location.

1.4 Project Architecture

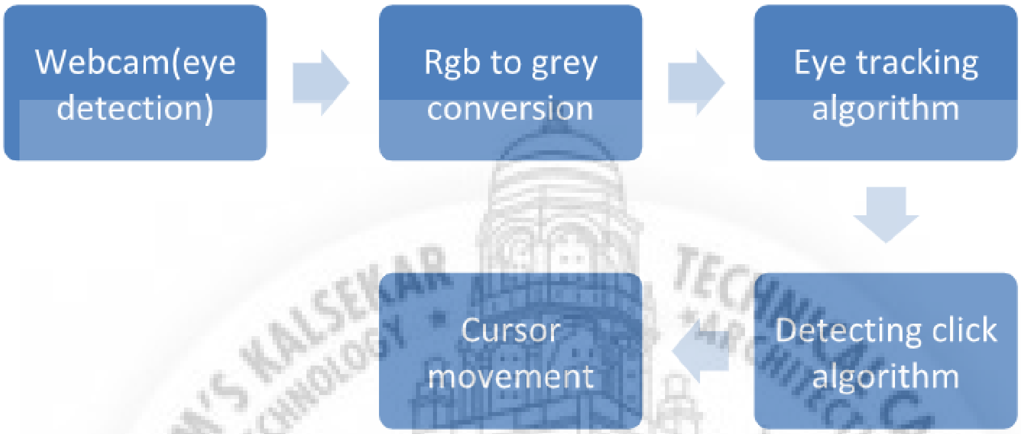

Figure 1.1: Project Architecture

1.5 Scope

The project will focus on creating a simplified and low-cost Eye Tracking System with a wireless network. Furthermore, this report is limited to hardware and software performance of the device, and possible applications and does not include analysis of marketability specifics or performance of current systems in the market.

Chapter 2

Background Research

2.1 Eye Movement

Eye movements are typically divided into two categories: fixations and saccades. Fixations occur when the eye gaze pauses in a certain position. For eye tracking purposes, fixations are used to denote a starting point for all eye movements and saccades. Saccades are when the eye gaze moves to another position. Humans alternate between fixations and saccades; this resulting series of fixations and saccades is a scanpath. Scanpaths are used to analyze cognitive intent, interest

and importance. The fovea provides the bulk of visual information. The periphery is less informative than the fovea. Figure 1 shows the fovea located in the macula region of the retina. The locations of the scanpaths during eye tracking signify the information that was processed. Fixations normally last for 200 ms when reading text and 350 ms when viewing a scene.

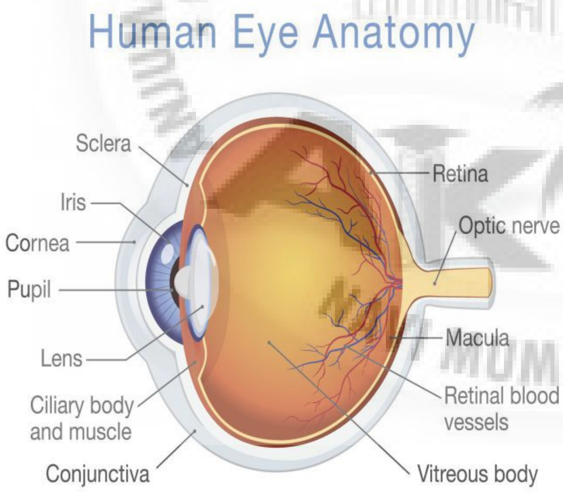

Fig 2.1:The Human Eye

2.2. Eye Tracking Techniques

There are currently two types of eye tracking techniques that are used: Bright Pupil and DarkPupil. Bright Pupil tracking creates a greater contrast between the iris and the pupil which allows for a more robust eye tracking. This greatly reduces any interference caused by eyelashes or other obscure features. Bright Pupil tracking additionally allows for tracking in lighting conditions, whether it is totally dark or very bright. This technique, however, is not effective for tracking outdoors. Dark Pupil tracking works to eliminate bright reflections. If the illumination source is offset from the path of the eye, then the pupil appears dark.

2.3 Image Sensors

An image sensor is a solid state device that takes an optical image and translates it into an electrical signal. An image sensor can be found in the design of any device that captures an image. One of the main uses of image sensors can be found in digital cameras. An image sensor is usually a Charge-Coupled Device (CCD) or a Complementary Metal-Oxide Semiconductor(CMOS). Both image sensors capture light using an array of small pixels on its surface and convert it into an electrical signal. The difference in these image sensors shows up in how they process the image. A Charge-Coupled Device is an analog device that enables the transportation of analog signals. The transportation of the signals is done in successive stages with the use of capacitors. As the light is captured on the surface of the device, the capacitors collect an electrical charge that corresponds to the light intensity at that location. A CCD starts by taking the charges of the first row of the array and placing them on the read out register. Next they are put into an amplifier and then into an analog-to-digital converter. The analog-to-digital converter takes the electrical signal and converts it into a voltage. After the row has been converted, the read out register is deleted. One by one, each row of the array is transferred to the read out register and converted.Then the sequence of voltages is sampled, digitized, and stored. A block diagram of a CCD sensor used in a camera can be seen in Figure 2.2

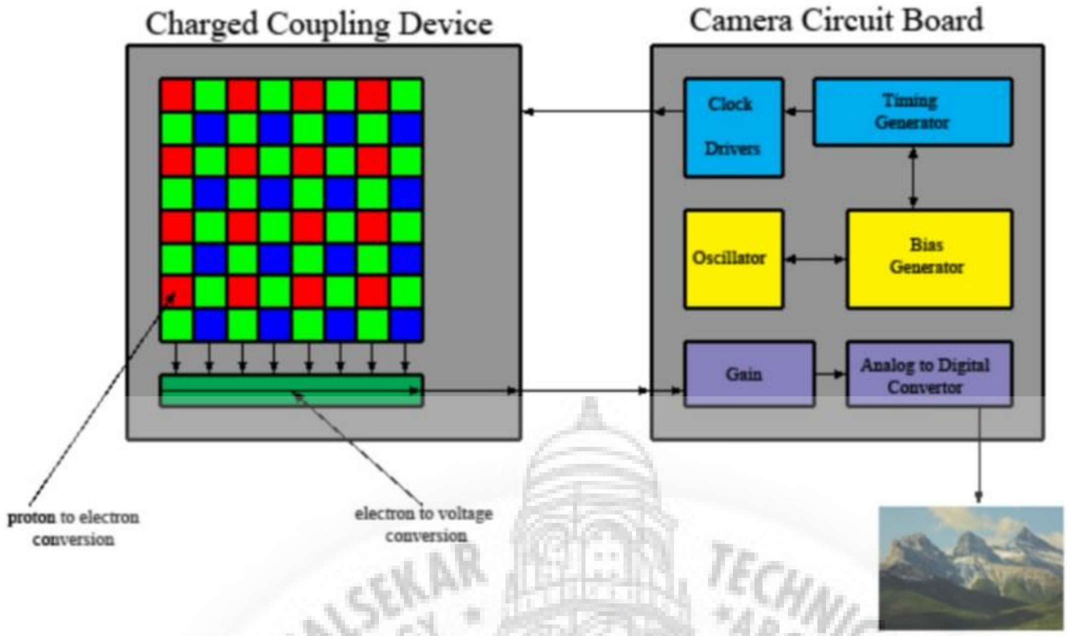

Figure 2.2 CCD Sensor

A Complementary Metal-Oxide Semiconductor is an active pixel sensor that uses complimentary and symmetrical pairs of p-type and n-type metal oxide semiconductor field effect transistors(MOSFET) for logic functions. CMOS image sensors use multiple transistors to amplify and move the charge provided by incoming photons of light, enabling the pixels to be read individually. A CMOS device has several transistors at each pixel that amplify and convert each pixel into a digital signal. The signal is then stored. A block diagram for a CMOS sensor used in a digital camera can be seen in Figure 2.3.

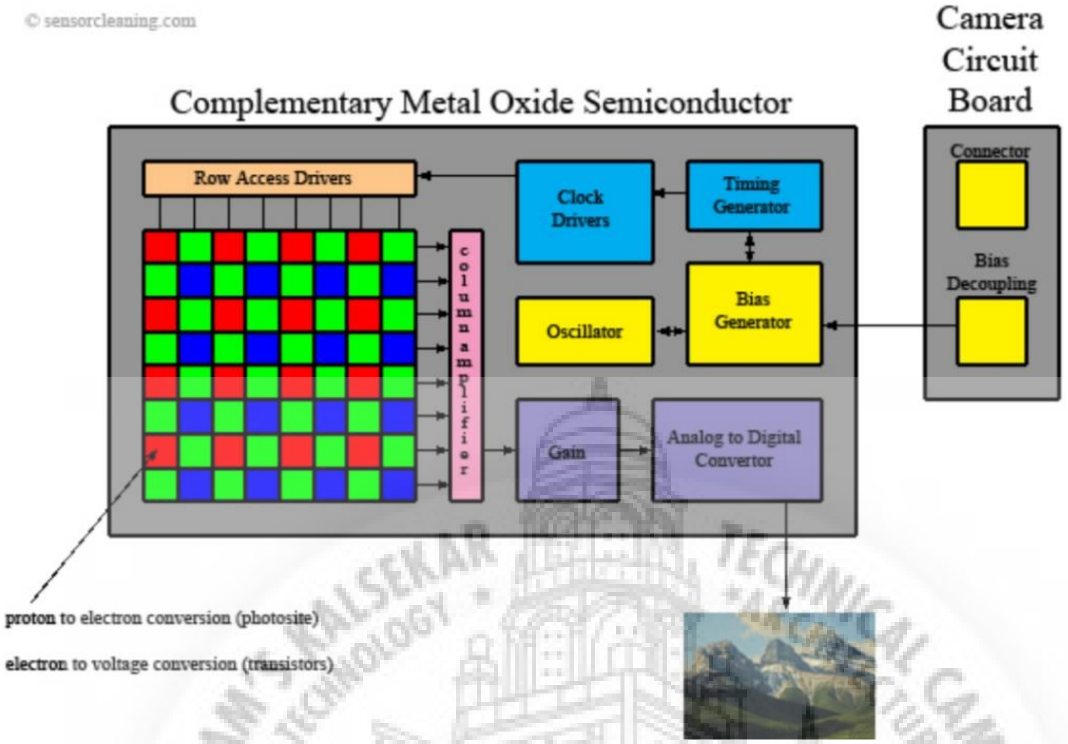

Figure 2.3:CMOS sensor

Until recently, implementation of items such as digital cameras was dominated by CCD image sensors. With the modern development of CMOS technology, the use of CCD image sensors has seen a large decrease. Some of the reasons for this decrease include cost and power consumption. A CMOS wafer is much cheaper to produce than a CCD wafer, which makes the use of CMOS image sensors in a system very inexpensive. A CMOS image sensor also uses much less power than that of a CCD image sensor.

2.4 The Department of Linguistics Research

The Department of Linguistics at The Ohio State University uses eye tracking in its

Psycholinguistics Lab to conduct research experiments. These research experiments investigate psychological and neurobiological factors that enable humans to acquire, use and comprehend language. A majority of the research done involves studies of children's ability to learn language. The lab uses two different eye tracking systems in their research. This equipment includes the ASL 6000 and the Tobii 1750.

2.5 The Center for Cognitive Science Research

The Center for Cognitive Science (CCS) at The Ohio State University uses eye-tracking equipment similar to the system Team B.I.T. will be designing. The CCS conducts experiments aimed at how people read and how their movements relate to their perception of the world around them. To achieve this, the CSS implements two different systems designed by ASL and Tobii.

2.5.1 ASL System

The ASL (Applied Science Laboratory) is a device worn on the head that uses an infrared camera to observe the both the pupil and the reflection from the cornea, and transmits the data to a computer which processes the signal and displays the pupil tracking data. The user wears the ASL and the device tracks the movement of the pupil as the user interacts with real world objects that can be touched or moved, as well as monitor-based visual tasks, such as reading text or observing images. A color camera is used to record the movement of the eye and displays the images on a monitor where the eye movement can be examined. The ASL tracks the orientation of the head via sensors and the subject’s distance from the PC monitor via magnetic sensors, one mounted on the ASL, and the other three feet behind the subject for additional precision. The ASL is fairly precise, but can become unreliable over time if not calibrated properly. Correct calibration can take up to 15 minutes, which further complicates usage of the device. This system is similar to the one Team B.I.T. will design, but will require less calibration, will be cheaper and potentially more accurate.

2.5.2 Tobii System

The Tobii is an advanced eye tracking system that includes a series of infrared cameras mounted into a specially fabricated PC monitor and a series of other sensors to track eye and head movement. The Tobii system processes images of the subjects face and eyes, as well as the reflection in the eyes. These images are used to estimate the 3D position in space of each eye and the target of the eye gaze.The Tobii does not require the subject to wear any equipment and the calibration is much faster and far more accurate than the ASL. While accurate, the Tobii system is incredibly expensive and not practical as a marketable consumer product or medical device. Additionally, this system is limited to computer monitor based experiments as opposed to also tracking the interaction with real world objects. The technical complexity of this system is well beyond the scope of this project.

Chapter 3

Methodology

The first step was to use a face detection algorithm locate the face on an image frame captured by an ordinary webcam. The next step was to detect only the eyes from this frame. We consider tracking only one eye movement for faster processing time. Then the iris movement was tracked. Since the color of the iris is black, its image has a significantly lower intensity compared to the rest of the eye. This helps us in easy detection of the iris region. Taking the left and right corners of the eye as reference points, the shift of the iris as the person changed his eyes focus was determined. The shift was then used to map cursor location on the test graphical user interface (GUI).

3.1 Program Analysis

The first step was to use a face detection algorithm locate the face on an image frame captured by an ordinary webcam. The next step was to detect only the eyes from this frame. We consider tracking only one eye movement for faster processing time. Then the iris movement was tracked. Since the color of the iris is black, its image has a significantly lower intensity compared to the rest of the eye. This helps us in easy detection of the iris region. Taking the left and right corners of the eye as reference points, the shift of the iris as the person changed his eyes focus was determined. The shift was then used to map cursor location on the test graphical user interface (GUI).

3.2 Implementation

The algorithm for controlling the cursor by the eye iris movement was achieved through the following steps:

3.2.1 Face detection

In order to capture the face image accurately, the user sat upright with the eye level parallel to the webcam as shown in the Fig. 3.1. The image of the user's face is captured using a MATLAB tool called vfm , using which images can be captured with the help of a webcam or any other imaging tools attached to the PC. Fig.3.2 shows the image captured by this tool

Figure 3.1: System setup for eye mouse

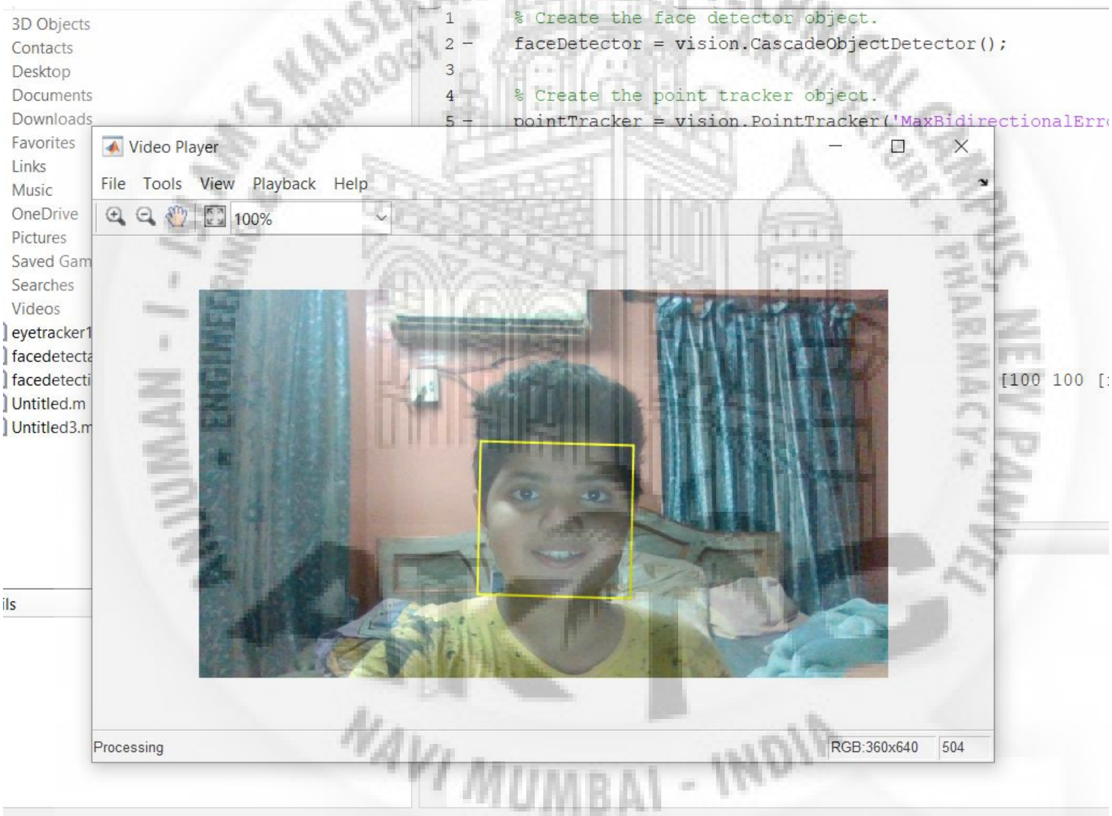

Figure 3.2:Image Detection And Image Capture

3.2.2 Extracting Eye Area

In order to extract the eyes region, the image of the face is divided into two equal horizontal areas. The upper part where the eyes are located is extracted as shown Fig. 3.2.

Figure 3.3: Eye Region Extraction

3.2.3 Extracting Eye Location

The image of one eye was then extracted and normalized in order to remove the background noises and then it was converted to binary image to enhance contrast. The normalized pixel (0 – 1 scale) values of the left eye image is shown in Fig. 3.4.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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7	1	1	1	0.9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	0.4	0.4	0.2	0.1	0	0.1	0.2	0.7	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	0.7	0.9	1	0.3	0.2	0	0.7	0.2	0	0	0.1	0.9	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	0.7	0.5	0	1	1	1	0.4	0.7	1	1	0.4	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	0.9	0.9	1	0.4	0.4	1	1	1	1	1	0.7	0	0.7	0	0.2	0	0	0.2	0.9	1	0.7	1	1	1	1	1	1	1	1	1	1
15	1	1	0.9	0.8	0.5	1	0.3	0.5	1	1	1	1	1	1	0.5	0.2	0.1	0	0.1	0	0.2	0.7	0.9	0.9	1	1	1	1	1	1	1	1	1	1
16	1	0.9	0.7	0.5	0.3	1	1	1	1	1	1	1	1	1	1	0.7	0	0	0.3	0.9	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	0.9	0.7	0.4	0.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	0.9	0.7	0.4	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	0.7	0.7	0.7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 3.4: Normalized pixels values of left eye image.

3.2.4 Extracting Iris Region

Since the iris region is black, corresponding pixels' values were very low and when the image was normalized, these values were approximated to zero. Hence the boundaries of iris region were determined as shown in the Fig. 3.5.

iris =

0	0	0	0.1000	0.4000
0	0	0	0	0
0	0	0	0	0
0	0	0	0	1.0000
0.9000	0	0	1.0000	1.0000

Figure 3.5: Pixel's intensity values in the iris area

3.2.5 Tracking Eye Movement

In order to avoid the head movement effect on the iris location, the two corners of the eye region were taken as reference, thus the iris movement was tracked accordingly.

3.2.6 Calculating Iris Shift

In order to calculate the movement within the eye as the user gaze on the screen, the user was asked to look at a central pattern on the screen and the iris boundaries are determined. The user was then asked to look at other pattern to the left, right up and down with respect to the central pattern. The shift in the iris was then calculated and was used to decide the direction and position of the cursor. Fig.3.6 shows the binary images of the eye when looking in different directions. In the Fig. 3.6, the image at the top was captured when the user was looking at the centre of the screen while the middle image was captured when the user was looking to the right and lower image when the user was looking to the left. The relative shift in the iris position is used to determine the cursor position on the test GUI shown in the Fig. 3.7.

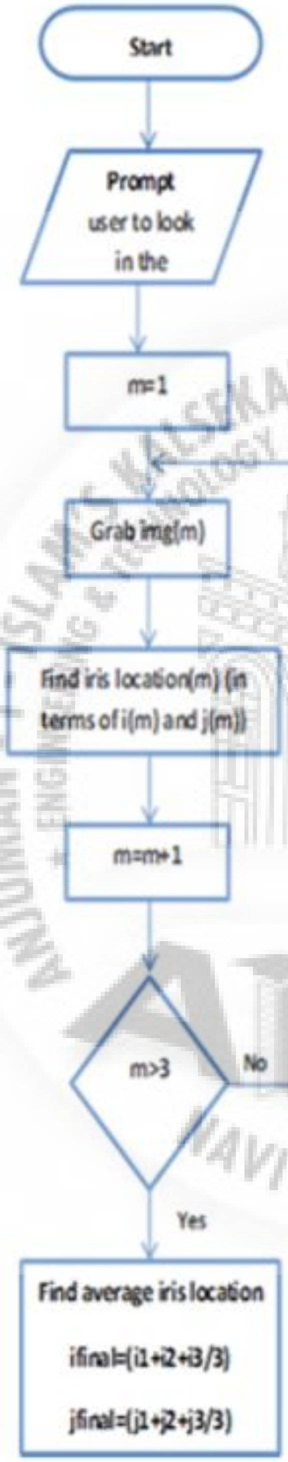
Figure 3.6: Shift in the Iris to left and right

Figure 3.7: Test GUI

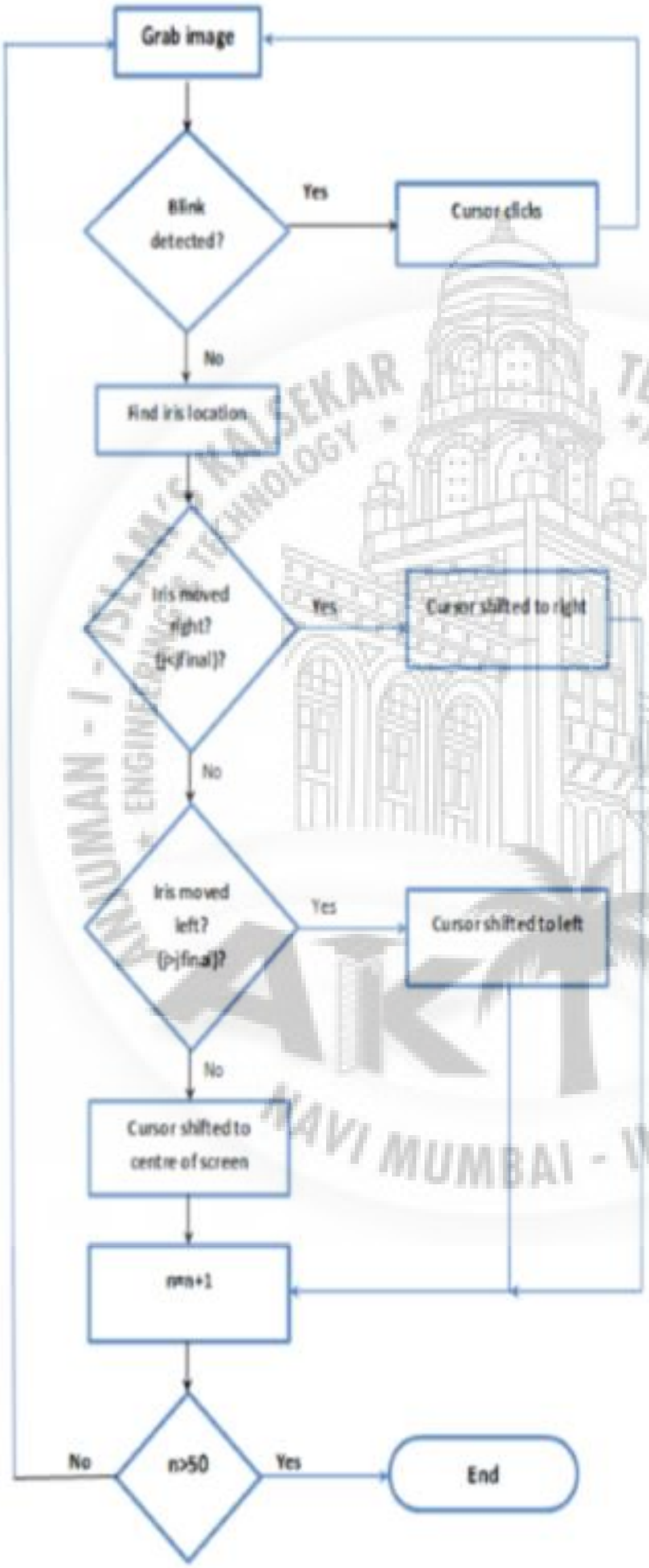
3.3 Algorithm

The flow chart of the MATLAB program that was developed to perform the various stages discussed in the sections 3.2.1- 3.2.6 is given in the below flowchart

3.3.1 Flowchart of iris detection algorithm



3.3.2 Flowchart of blink detection algorithm



3.4 Project Requirement

As the project is image processing oriented the software requirement is more as compared to hardware.

3.4.1 Software Requirement

MATLAB.

3.4.2 Hardware Requirement

1.PC.

2.Web Camera.

Chapter 4

Market Potential

4.1 Market Potential

The proposed system will have vast impact on the currently used system there can be replacement of touchscreen technology and the implementation of an image processing based module can be done in an economical manner.

4.1.1 Competitive Advantages

As the computer technology is grow up, the importance of human computer interaction is rapidly increasing. Most of the mobile devices and laptops are using touch screen technology. But this technology is still not cheap enough to be used on desktop systems. Creating a virtual human computer interactive module such as mouse or keyboard, can be an alternative way for the touch screen. The motivation is to create an object tracking application to interact with computer develop a virtual human computer interaction device.

Chapter 5

Results And Conclusion

5.1 Results

A MATLAB based algorithm for face detection, eye region extraction, iris tracking and cursor control was successfully developed and tested. A test GUI comprised of nine boxes on the computer screen was used for the validation of the cursor movement as shown in Fig. 3.7. The iris movement was accurately tracked and the cursor was successfully moved to all nine boxes in the test GUI. Up and down movement however, was not highly consistent and the system requires further enhancement. Clicking action was also successfully tested through a change in the color of boxes.

5.2 Conclusion

A system that enables a disabled person to interact with the computer was successfully developed and tested. The method can be further enhanced to be used in many other applications. The system can be adapted to help the disabled to control home appliances such as TV sets, lights, doors etc. The system can also be adapted to be used by individuals suffering from complete paralysis, to operate and control a wheelchair. The eye mouse can also be used to detect drowsiness of drivers in order to prevent vehicle accidents. The eye movement detection and tracking have also potential use in gaming and virtual reality.

Chapter 6

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