Eye-Clicker

Draft System Design - Rev1

SFWR ENG 4G06 / MECHTRON 4TB6
GROUP 8

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Contents

1 Design Timeline

1.1 Revision History

Date	Revision	Authors
Jan 10, 2020	0	All group members
March 13, 2020	1	All group members

1.2 Road Map

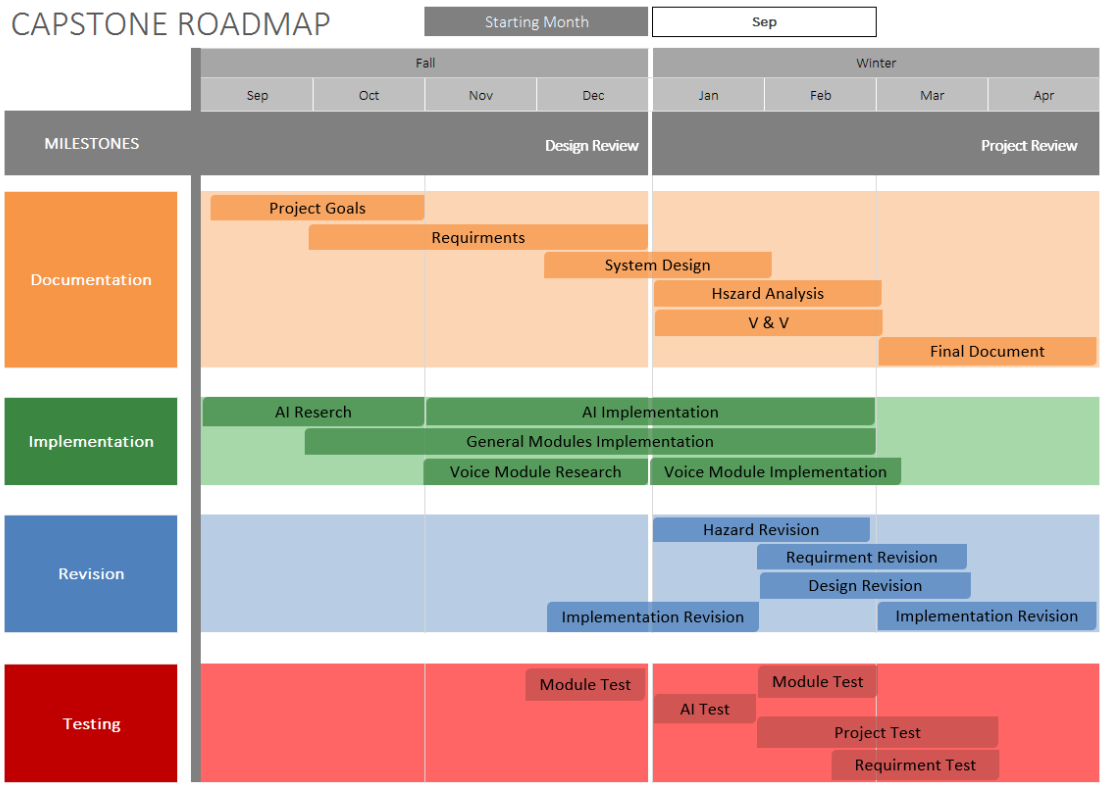

Figure 1: Road Map

2 Purpose

The purpose of the EyeClicker is to give our users an alternate method to use their computer. With our device, a user will be able to control their computer or laptop without having to use a mouse, and instead use their eyes. This is especially helpful to users who have limited mobility with their arms, those who are injured, or simply someone who wants to rest. Given an alternate method of using a computer, our device can help more people use a computer comfortably and be connected to the digital world we live in.

Eye-tracking has become fairly popular over recent times, and our EyeClicker will utilize this concept to provide a full user experience that mimics the behavior of a mouse. The EyeClicker will identify where the user is looking to position the cursor to that spot on the screen. It will also track a unique set of simple eye movements/actions as well as certain voice commands to deliver the appropriate response. Whether the user wishes to click, drag or enter text the EyeClicker will provide all those functionalities simply though tracking the eye and voice control.

2.1 Scope

The project will be based around tracking user's eye movements and making the cursor react, including but not limited to moving the cursor, left-clicking and click and dragging. This will be achieved through image processing, more specifically, human eye recognition and a well-developed algorithm to control mouse actions.

In-scope functionality items for the EyeClicker including the following:

- Calculate the position the user is looking on the computer display
- Calibration system to increase the accuracy of the EyeClicker
- Allows user to perform a left-click as well as dragging with certain special actions that can be performed with voice commands
- Be able to let user disable the EyeClicker system to prevent misoperation
- Provide a functional GUI to enable/disable the EyeClicker and enter the calibration system

The following items are out of scope: Allows user to control the cursor with voice input

2.2 Context Diagram With Boundaries

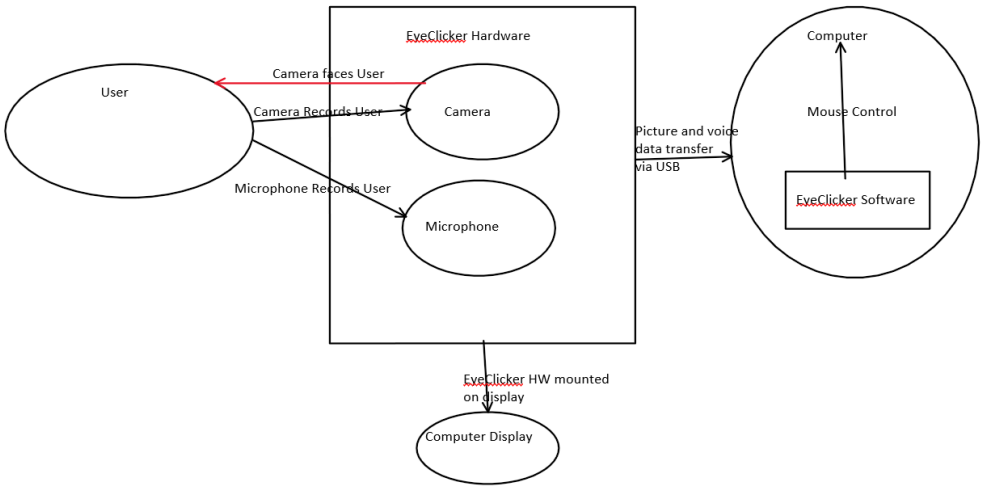

Figure 2: Context Diagram

2.3 Diagram of Components

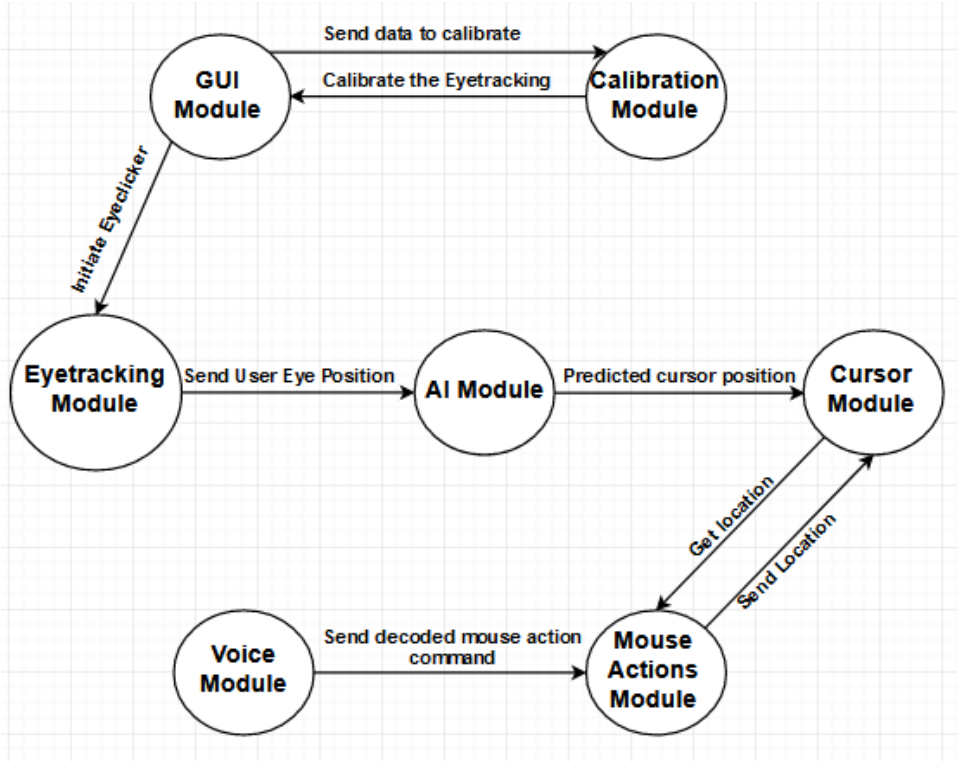

Figure 3: Diagram of Components

2.4 Assumptions

A1	There will be sufficient lighting in the environment of eye detection.
Rationale	The eyes must be visible to the camera for the system to detect where the user is looking on the screen.

A2	There is only one pair of eyes in the view of the camera that belongs to the same person.
Rationale	Having more than one pair of eyes will be very confusing to the system and it is difficult to determine who is the primary user.

A3	The camera is looking generally in the direction of the user's face. The eyes are easily seen and are not at an obscure angle.
Rationale	This helps with the detection of the eyes and will greatly improve the accuracy of eye tracking.

A4	The user must recalibrate if the camera or user position is altered.
Rationale	The calibration is relative to the user and camera position. Recalibration is necessary for eye detection as the new position will be foreign to the system.

A5	The user's eyes are not extremely far from the camera such as more than 1 meter away.
Rationale	If the eyes are really small, the error of margin will be very high as very small movements could be the difference between the left and right ends of the screen.

A6	The user follows the calibration steps appropriately.
Rationale	If the user does not follow the guidelines of the calibration and perform all the steps, the eye detection may be skewed.

3 System Variables

3.1 Monitored and Controlled Variables

Monitored Variables

Name	Type	Range	Units	Comment(s)
image_frame	Binary	N/A	N/A	Video input captured by web camera
coord_landmark_left	Two dimensional array of floating numbers	[0,1]	Percent	Coordinates of points around user's left eye(in percentage)
coord_landmark_right	Two dimensional array of floating numbers	[0,1]	Percent	Coordinates of points around user's right eye(in percentage)
coord_pupil	Array of floating numbers	[0, 1]	Percent	Coordinates of points indicating left and right pupil positions(in percentage)
get_cursor_xy	Boolean	[0, 1]	Percent	Signal to tell the module to output the current position of the cursor
voice_input	Binary	N/A	N/A	Voice commands from the user
coord_pupil_training	Two dimensional array of floating numbers	[0, 1]	Percent	Array of coordinates of points indicating left and right pupil positions(in percentage)
coord_pupillooking_training	Two dimensional array of floating numbers	[0, 1]	Percent	Array of coordinates of points indicating where the user's eyes are looking at on the screen(in percentage)
GUI_start	Boolean	[0,1]	N/A	Signal for initializing the Eyetracking Module
GUI_exit	Boolean	[0,1]	N/A	Signal for exiting the GUI Module
GUI_calibration	Boolean	[0,1]	N/A	Signal for initializing the Calibration Module

Controlled Variables

Name	Type	Range	Units	Comment(s)
predicted_cursor_position	Array of floating numbers	[0, 1]	N/A	The coordinate where the cursor will move to
cursor_xy	Array of floating numbers	[0,1]	N/A	Current coordinate of the cursor(in percentage)
click_left	Boolean	[0,1]	N/A	Perform a double left click action if Click_left = 1
click_right	Boolean	[0,1]	N/A	Perform a right click action if Click_right = 1
init_calibration	Boolean	[0, 1]	N/A	Initially 0, 1 when user clicks Calibrate, set to 0 when calibration is initiated
calibration_in_proccess	Boolean	[0, 1]	N/A	Set to 1 when calibration is in process, else 0
predicted_cursor_position	Array of floating numbers	[0, 1]	N/A	Coordinates of points indicating where the user's eyes are looking at on the screen(in percentage)
Init_eyetracking	Boolean	[0,1]	N/A	Initialize the Eyetracking Module
Init_calibration	Boolean	[0,1]	N/A	Initialize the Calibration Module

3.2 Constants

Constants

Constant	Unit	Value
Camera Frequency*	Pictures / Second	10
calibrationCoordinates[5]**	(x%,y%) ***	(0,0), (1,0), (0,1), (1,1), (0.5,0.5) where 1 = 100%

* Camera Frequency is the frequency the camera will take pictures and feed it to the computer.

** Five coordinates used during the calibration procedure

*** x% is percentage is the horizontal percentage of the screen you are looking at where the left edge is 0% and the right edge is 100%. y% is percentage is the vertical percentage of the screen you are looking at where the top edge is 0% and the bottom edge is 100%

4 Behaviour Overview

- **Eye-Tracking Module:** Provide eyelid and pupil position information based on web-cam video. This data will be communicated to different components of the system.
- **Cursor Module:** Responsible for moving the cursor to given locations as well as getting the current coordinates of the cursor.
- **Voice Module:** Responsible for detecting voice commands from the user and initiating the response.
- **Mouse Action Module:** Responsible for executing mouse click actions.
- **Calibration Module:** Responsible for increasing the accuracy of the Eye-Clicker.
- **AI Module:** Responsible for training the data by machine learning algorithms and using the algorithm to detect the desired cursor position.
- **GUI Module:** Responsible for interacting with users by displaying information and provide actions.

5 Component Traceability

Component Module:	Performance Requirement:
Eye-Tracking Module	Performance Requirement 1
	Performance Requirement 2
	Performance Requirement 5

Component Module:	Performance Requirement:
Cursor Module	Performance Requirement 1
	Performance Requirement 5

Component Module:	Performance Requirement:
Voice Module	Performance Requirement 3
	Performance Requirement 4

Component Module:	Performance Requirement:
Calibration Module	Performance Requirement 1

Component Module:	Performance Requirement:
AI Module	Performance Requirement 1
	Performance Requirement 2
	Performance Requirement 5

6 Component Overview

6.1 Eye-Tracking

6.1.1 Description

This module will capture video input from a web camera at a minimum of 10fps (frames per second). The web camera will constantly retrieve image frames of the user and process the image data by the algorithm written with an openCV library. The output of the algorithm will be the coordinates of the points around the user's eyes and the point indicating the pupil's position (in percentage relative to the screen, for example the middle point will have a coordinate of (0.5, 0.5)).

6.1.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
image_frame	Video Frame	N/A	N/A	Video input captured by web camera
eye_tracking_activated	Boolean	[0, 1]	N/A	True if this module is activated

Outputs:

Output Name	Output Type	Range	Units	Comments
coord_landmark_left	Two dimensional array of floating numbers*	[0,1]	Percent	Coordinates of points around user's left eye (in percentage)
coord_landmark_right	Two dimensional array of floating numbers*	[0,1]	Percent	Coordinates of points around user's right eye (in percentage)
coord_pupil_left	Array of 2 floating numbers	[0, 1]	Percent	Coordinates of points indicating left pupil position (in percentage)
coord_pupil_right	Array of 2 floating numbers	[0, 1]	Percent	Coordinates of points indicating right pupil position (in percentage)

*the array will be in essence a list of points

6.1.3 Exception Handling

Input Name	Input Type	Exception	Exception Handling
image_frame	Video Frame	User eye blinked	Drop the image frame so it will not be analyzed
eye_tracking_activated	Boolean	N/A	N/A

6.1.4 Timing Constraints

The algorithm must be efficient enough to give out the coordinate data within the limited delay time (350 ms).

6.1.5 Initialization

The module is initialized by clicking activate in the GUI module.

6.1.6 Web Camera specifications

Video resolution: 1920*1080
Interface: USB 2.0/1.1

6.2 Cursor

6.2.1 Description

This module will receive predicted cursor position from the trained AI model and move the cursor to the predicted location.
The module will start to move the cursor once the getting position signal is set to true.

6.2.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
predicted_cursor_position	Array of floating numbers	[0, 1]	N/A	The coordinate where the cursor will move to
get_cursor_xy	Boolean	[0, 1]	N/A	Signal to tell the module to output the current position of the cursor

Outputs:

Output Name	Output Type	Range	Units	Comments
cursor_xy	Array of floating numbers	[0,1]	N/A	Current coordinate of the cursor(in percentage)

6.2.3 Exception Handling

Input Name	Input Type	Exception	Exception Handling
predicted_cursor_position	Array of floating numbers	N/A	N/A
get_cursor_xy	Boolean	N/A	N/A

6.2.4 Timing Constraints

The module must provide cursor coordinates in real time for accuracy purpose.

6.2.5 Initialization

The module is initialized at the start-up of the Eye-Clicker.

6.3 Voice

6.3.1 Description

This module will receive sound information from a microphone. The microphone is constantly retrieving sounds from the surroundings and it is activated when the user says "Hey Eye-Clicker". The available commands are "Hey Eye-Clicker, left click", and "Hey Eye-Clicker, right click".

6.3.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
voice_input	Binary	N/A	N/A	Voice commands from the user

Outputs:

Output Name	Output Type	Range	Units	Comments
click_left	Boolean	[0,1]	N/A	Perform a double left click action if click_left = 1
click_right	Boolean	[0,1]	N/A	Perform a right click action if click_right = 1

6.3.3 Exception Handling

Input Name	Input Type	Exception	Exception Handling
voice_input	Byte Data Stream	Unknown voice commands	N/A

6.3.4 Timing Constraints

The information must process in time for ease of use for the user.

6.3.5 Initialization

The module is initialized at the start-up of the Eye-Clicker.

6.4 Mouse Actions

6.4.1 Description

This module will communicate with the computer system to perform clicking actions. It takes certain outputs from Voice module as the input, and performs the corresponding mouse click actions.

6.4.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
click_left	Boolean	[0,1]	N/A	Output from Voice module
click_right	Boolean	[0,1]	N/A	Output from voice module

Outputs:

Output Name	Output Type	Range	Units	Comments
left_click	N/A	N/A	N/A	OS left click actions when Click_left = 1
right_click	N/A	N/A	N/A	OS right click actions when Click_right = 1

6.4.3 Exception Handling

Input Name	Input Type	Exception	Exception Handling
click_left	Boolean	Click_left = 0	Do nothing when Click_left = 0
click_right	Boolean	Click_right = 0	Do nothing when Click_right = 0

6.4.4 Timing Constraints

The module should process the input right after Voice module gives an output with a maximum response time of 3 seconds (Performance Requirement 5).

6.4.5 Initialization

The module works alongside with Voice module. It is initialized at the same time as the Voice module.

6.5 Calibration

6.5.1 Description

This module will be used to calibrate the Eye-Clicker to improves its accuracy. It will do this by training an AI model. The input and output data for the model will be gathered by entering "Calibration" through the GUI. Once the mode is entered, the system will ask the user to follow the cursor with their eyes. The Calibration module will then use the Cursor module to move the cursor a maximum of 30 seconds. During this 30 second calibration time the Eye-Tracking module will track the eye position coordinates in synchronous with cursor module tracking mouse coordinates. This data will then be used to further train the AI module uniquely for the user.

6.5.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
init_calibration	Boolean	[0, 1]	N/A	Initially 0, 1 when user clicks Calibrate, set to 0 when calibration is initiated

Outputs:

Output Name	Output Type	Range	Units	Comments
calibration_in_proccess	Boolean	[0, 1]	N/A	Set to 1 when calibration is in process, else 0

6.5.3 Timing Constraints

The maximum length of time the user will need to track the cursor with their eyes will be 30 seconds.

6.5.4 Initialization

The Calibration module will be initiated through the GUI menu.

6.6 AI module

6.6.1 Description

This module will be used to take the coordinate of landmark and pupil points as input to predict user's desired cursor position based on machine learning algorithm. At first, AI module will be used to train a basic algorithm based on the data eye-tracking module gathered. It will also be used to improve its prediction accuracy by taking user's calibration data as training data.

6.6.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
coord_landmark_left_traning	ArrayList of two dimensional array of floating numbers	[0, 1]	Percent	An arraylist of coordinates of points indicating left and right pupil positions(in percentage)
coord_landmark_right_traning	ArrayList of two dimensional array of floating numbers	[0, 1]	Percent	An arraylist of coordinates of points indicating where the user's eyes are looking at on the screen(in percentage)
coord_pupil_left_training	ArrayList of an array of 2 floating numbers	[0, 1]	Percent	An arraylist of coordinates of points indicating left pupil position (in percentage)
coord_pupil_right_training	ArrayList of an array of 2 floating numbers	[0, 1]	Percent	An arraylist of coordinates of points indicating left and right pupil positions(in percentage)
coord_landmark_left	Two dimensional array of floating numbers	[0,1]	Percent	Coordinates of points around user's left eye (in percentage)
coord_landmark_right	Two dimensional array of floating numbers	[0,1]	Percent	Coordinates of points around user's right eye (in percentage)
coord_pupil_left	Array of 2 floating numbers	[0, 1]	Percent	Coordinates of points indicating left pupil position (in percentage)
coord_pupil_right	Array of 2 floating numbers	[0, 1]	Percent	Coordinates of points indicating right pupil position (in percentage)

Outputs:

Output Name	Input Type	Range	Units	Comments
predicted_cursor_position	Array of floating numbers	[0, 1]	N/A	Coordinates of points indicating where the user's eyes are looking at on the screen(in percentage)

6.6.3 Exception Handling

Input Name	Input Type	Exception	Exception Handling
invalid_pupil_coordinate	Array of float	Coordinate number is out of range	N/A

6.6.4 Timing Constraints

1.The process of training the AI should not be more than 20 seconds.
2.The process of using the existing AI model to predict desired cursor position should not be more than 400ms.

6.6.5 Initialization

The module is initialized at the start-up of the Calibration module.

6.7 GUI

6.7.1 Description

The GUI(graphical user interface) module is a system of interactive visual components for our software. This module will display objects that convey information, and represent actions such as calibration and exit the program which can be taken by the user.

6.7.2 Inputs and Outputs

Inputs:

Input Name	Input Type	Range	Units	Comments
GUI_start	Boolean	[0,1]	N/A	Signal for initializing the Eyetracking Module
GUI_calibration	Boolean	[0,1]	N/A	Signal for initializing the Calibration Module

Outputs:

Output Name	Input Type	Range	Units	Comments
init_eyetracking	Boolean	[0,1]	N/A	Initialize the Eyetracking Module
init_calibration	Boolean	[0,1]	N/A	Initialize the Calibration Module

6.7.3 Exception Handling

Input Name	Input Type	Exception	Exception Handling
init_eyetracking	Boolean	ModuleAlreadyInited	Do nothing
init_calibration	Boolean	ModuleAlreadyInited	Do nothing

6.7.4 Timing Constraints

The GUI Module should move the cursor or execute the clicking no longer than 100 millisecond right after Cursor Module and Mouse Action Module give the output.

6.7.5 Initialization

The module is initialized at the start-up of the Eye-Clicker.

7 Likelihood of Change

Module	Likelihood of Change	Rationale
Eye-Tracking Module	Very Unlikely	Key Implementation aspect
Cursor Module	Very Unlikely	Key Implementation aspect
Voice Module	Very Unlikely	Key Implementation aspect
Mouse Actions Module	Very Unlikely	Key Implementation aspect
Calibration Module	Very Unlikely	Key Implementation aspect
AI module	Very Unlikely	Key Implementation aspect
GUI Module	Very Unlikely	Key Implementation aspect

8 Normal Operation

During the calibration stage, the user should be within the effective working distance of the EyeClicker (60cm of the screen). Sitting too far away from the camera causes inaccuracy or worsens the ability of EyeClicker to locate users' eyes and to control the cursor accurately.

During the working stage after calibration, the user now can navigate the cursor using their eye movements. Left and right clicking are the basic functions the user can operate. These functions operate at the optimal level when the user is sitting at a stable position and as close to the position that the system was previously calibrated in.

Speech recognition is one of the solutions to help the user have more capability to do a task. When using speech recognition, the user should speak at a steady pace to obtain optimal performance. The speech recognition will also be used to activate the left and right click mouse actions through predetermined commands that the user will need to learn.

9 Handling Undesired Event

- Unable to click the desired point on the screen. When the user is having trouble clicking the desired item, one should redo the calibration to improve the accuracy. To access the calibration test, click the "Calibration" button in the GUI.
- EyeClicker cannot locate the user's eyes after turning his/her head away from the screen. When the user looks away from the screen for too long, EyeClicker might lose track of the locations of the user's eyes. To solve this problem, the user should move closer to the camera/screen (around 60cm away) and stare at the middle of the screen for a short amount of time.

10 Requirements

The scope of the project will be limited to meeting the requirements on a display size of 35.56cm (14inches) with a 16:9 aspect ratio while the user is 60cm. If desired the software will still be compatible with different display sizes, aspect ratios and viewing distances, however the accuracy may be degraded. This user setup constraint allows for simplification when training the AI model.

Performance Requirements:

- The deviation of detecting where the EyeClicker thinks user is looking compared to actual position the user it looking at must be smaller than 5cm while within effective working distance of the EyeClicker (60cm from the screen).
- The latency of detecting whenever users' eyes are moving must be shorter than 150 milliseconds.
- The latency of receiving, translating, and executing user's voice command must be shorter than 3 seconds.
- The accuracy of speech recognition must be greater than 65 percent.
- The latency of moving the cursor to where the user is looking shall be shorter than 300 milliseconds.

Other Requirements:

1. The system shall have enough accuracy to reasonably track where the users' eyes on the screen.
    - Rationale: Needed to allow for accurate cursor control for the user.
2. The system shall precisely calculate how long has users focused on one spot.
    - Rationale: The system should know how long has users focused on one spot to enable the clicking functionality.
3. The system shall have 16 predetermined points for calibration.
    - Rationale: The system should have at least 16 predetermined calibration points to improve the accuracy of detecting where the user is looking at on the screen.
4. The system shall translate users' voice correctly into system commands.
    - Rationale: The system should allow users to say commands while avoiding unintended actions.
5. The system shall allow the user to perform mouse click actions through voice commands.
    - Rationale: To meet the goal of allowing users to perform left and right click through the system.
6. The UI can initialize all the voice, calibration, and eye-tracking modules effortlessly.
    - Rationale: Provide a UI to give user feedback for the system's operation. This UI also needs to be able to enable the other modules for the system to be stable.

11 Appendix

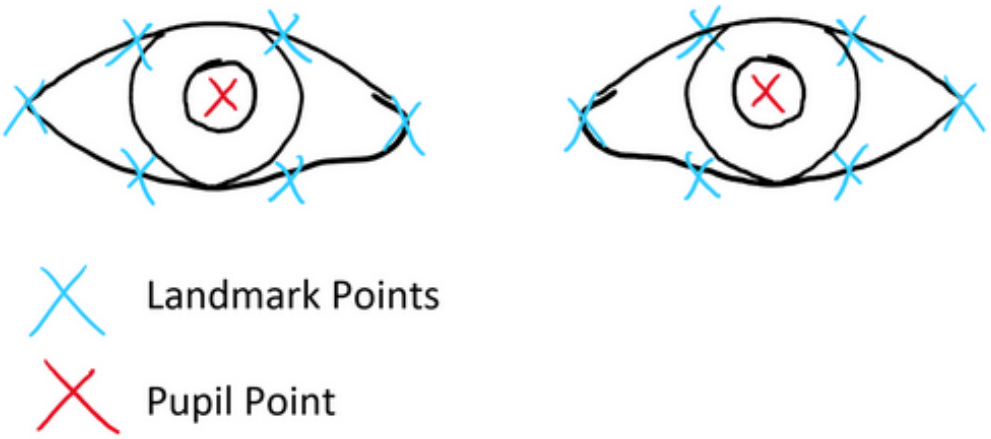

Figure 4: Eyetracking Coordinates